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 (71)(72) Applicant and Inventor: CHEN, Jay, C. [-/US]; 1335 Blackstone Road, San Marino, CA 91108 (US).
 (74) Agent: GELFOUND, Craig, A.; Christie, Parker & Hale, LLP, P.O. Box 7068, Pasadena, CA 91109-7068 (US).

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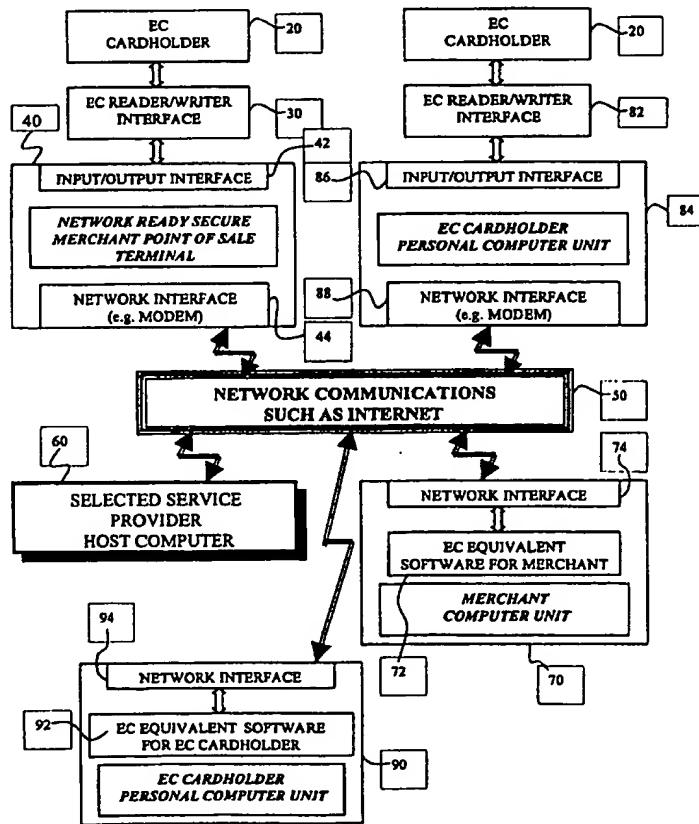
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(54) Title: A CRYPTOGRAPHIC SYSTEM AND METHOD FOR ELECTRONIC TRANSACTIONS

(57) Abstract

An electronic transaction system, which facilitates secure electronic transactions among multiple parties including cardholders (20), merchants (70), and service providers (SP) (60). The system involves electronic cards, commonly known as smart cards, and their equivalent computer software package. The card mimics a real wallet and contains commonly seen financial or non-financial instruments such as a credit card, checkbook, or driver's license. A transaction is protected by a hybrid key cryptographic system and is normally carried out on a public network such as the Internet. Digital signatures and random numbers are used to ensure integrity and authenticity. The card utilizes secret keys such as session keys assigned by service providers (SPs) to ensure privacy for each transaction. The SP is solely responsible for validating each participant's sensitive information and assigning session keys. The only trust relationship needed in a transaction is the one that exists between individual participants and the SP.



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1 **A CRYPTOGRAPHIC SYSTEM AND METHOD
FOR ELECTRONIC TRANSACTIONS**

5 **FIELD OF THE INVENTION**

The present invention relates generally to a cryptographic system and method for secure electronic transactions, and more particularly to an electronic card, which takes the form of a "smart card" and/or its equivalent software.

10 **BACKGROUND OF THE INVENTION**

The generic term, "smart card," generally denotes an integrated circuit (IC) card, that is, a credit-card-size piece of plastic with an embedded microchip. The IC chip on a smart card generally, but not necessarily, consists of a microprocessor (the CPU), read-only memory (ROM), random access memory (RAM), an input/output unit, and some persistent memory such as electrically erasable programmable read-only memory (EEPROM). The chip can perform arithmetic computations, logic processing, data management, and data communication.

15 Smart cards are mainly of two types: contact and contact-less. The International Standard Organization (ISO) has established specifications for such electronic cards under the ISO series. In particular, ISO 7816 applies to integrated circuit(s) cards. Because of its computing capability, a smart card can support a multitude of security features such as authentication, secured read/write, symmetric key and asymmetric key encryption/decryption. These smart card security features make it well suited for electronic commerce where data security and authenticity are of primary importance.

20 Smart card use has found application in many specialized fields such as mass transportation, health insurance, parking, campus, gas, etc. And its potential use in electronic commerce and other financial areas are gaining popularity at a rapid pace. U.S. Pat. No. 5,521,362, issued to Robert S. Power on May 28, 1996, entitled "Electronic purse card having multiple storage memories to prevent fraudulent usage and method therefor," describes an electronic purse application. Power's invention demonstrates a smart card's capability to be used as a secure financial instrument and not just as a storage device.

25 As advances in technology push smart-card chip computing to higher speeds and larger memory capacity, the concept of a "multi-application" smart card is increasingly becoming economically and physically feasible. U.S. Pat. No. 5,530,232 issued to Douglas C. Taylor on June 25, 1996, entitled "Multi-application data card," describes a multi-application card, which is capable of substituting for a plurality of existing single-application cards and satisfying both financial and non-financial requirements. The multi-application card uses a conventional data link to connect between the smart card and the remote service provider. Taylor's invention, the multi-application card, does not relate to any kind of open network or cryptographic method.

30 U.S. Pat. No. 5,544,246 issued to Mandelbaum et al. on Aug. 5, 1996, entitled "Smart

1 card adapted for a plurality of service providers and for remote installation of same," describes
a smart card, which allows different service providers to coexist on the same smart card. Each
service provider is considered a user of the smart card and is installed on the card by the
issuer/owner of the smart card. Each user is allowed to build a tree-like file structure and protect
5 it with a password file. Mandelbaum's invention depicts a smart card allows for the creation and
deletion of multiple applications. Mandelbaum's smart card controls the access to each
application by using an appropriate password file.

U.S. Pat. No. 5,671,279 issued to Taher Elgamal on September 23, 1997, entitled
"Electronic commerce using a secure courier system," describes a system for implementing
10 electronic commerce over a public network using public/private key cryptography. The Elgamal
patent did not mention the use of a smart card as a tool in conducting the electronic commerce
and the participants were authenticated through the use of digital certificates. The secure courier
system requires a secured channel such as a Secure Socket Layer (SSL) between the trading
parties over an open network such as the Internet.

15 1. U.S. Pat. No. 5,790,677, issued to Fox et al. on August 4, 1998, entitled "System
and method for secure electronic commerce transactions," describes a system and method
having a registration process followed by a transaction process. During the registration
phase, each participant of a transaction registers with a trusted credential-binding server
20 by sending to the server a registration packet. The server produces unique credentials
based upon the request received and sends them to the request originator. During the
transaction phase, the originator of the transaction requests, receives and verifies the
credentials of all intended recipients of the commerce document and/or instrument and
encrypts the document and/or instrument using the public key of the individual recipient.
Thus, each receiving party can decrypt and access the information intended only for him.
25 Fox's patent describes a process which reflects the theme of the so called "Secure
Electronic Transaction" (SET) standard which is an ongoing effort supported by several
major financial and software companies to establish a digital certificate and certificate
authority based electronic commerce system.

30 U.S. Pat. No. 5,796,840 issued to Derek L. Davis on August 18, 1998, entitled "Apparatus
and method for providing secured communication," describes a semiconductor device, which is
capable of generating device-specific key pairs to be used in subsequent message authentication
and data communication. The semiconductor device uses public/private key cryptography to
ensure the authenticity of two communicating parties.

35 U.S. Pat. No. 5,534,857 issued to Simon G. Laing and Matthew P. Bowcock on July 9,
1996, entitled "Method and System for Secure, Decentralized Personalization of Smart Cards,"
describes a method and apparatus for securely writing confidential data from an issuer to a
customer smart card at a remote location. A mutual session key for enciphering data transfer
between a secure terminal and a secure computer is generated by using a common key stored in

1 the secure computer and a retailer smart card.

It is clear from the inventions mentioned above that the architecture of a secure electronic commerce system involves a public key infrastructure and digital certificate authority associated with it.

5 On an open network, a secret key-based system is less flexible in terms of key distribution and key management, and is more subject to malicious attack. On the other hand, a public/private key-based system, with all its advantages over the secret key system, has its own daunting task of authenticating transaction parties to one another. The current invention presents another system and method, which replaces the need for certificate authorities and digital
10 certificates. The current invention is a hybrid system for electronic transactions. The hybrid system uses public/private keys during the key exchange phase and uses a session key as a secret key during the transaction phase.

SUMMARY OF THE INVENTION

15 The invention is a cryptographic system and method for electronic transactions by using an electronic card (EC) in the form of a smart card or equivalent software and communicating over a communications network.

20 The preferred embodiment of the invention uses an open network, such as the Internet. Alternative embodiments of the invention may use other types of networks. An embodiment of the invention may either use a physical smart card, or alternatively, a smart card, which is implemented as computer software package and runs on a computing device such as a personal computer (PC). Likewise, a merchant involved in a transaction may use a merchant device, which is a point-of-sale terminal, or a device, which uses software on a host computer to communicate with an EC and a service provider. When a smart card is used, a smart card reader
25 is also needed to allow the card to communicate with a host device, such as a network ready merchant terminal, a PC, or any other electronic device, which is capable of supporting smart card transactions.

30 In a public key and digital certificate based system, transaction participants exchange public information through the use of digital certificates or other electronic credentials which are issued and certified by a certificate authority (CA) or credential binding server. The communication between the CA or the server and each participant of the transaction must be secure. Random numbers and digital signatures are used to ensure the authenticity and validity
35 of the messages transmitted among the participants.

35 The cryptographic system and method of the preferred embodiment of the invention also uses public/private key cryptography, but it works in a slightly different way. The cryptographic system and method does not seek to create another kind of trust relationship as the one that exists between holders of digital certificates and the certificate authorities. It particularly targets large membership-based financial institutions such as a large credit card company and all its

1 cardholders, or a major bank and all its ATM cardholders as its potential users. Non-financial institution can also use this cryptographic system and method to conduct commercial or non-financial transactions over a network.

5 A service provider (SP) provides some service to its members. Financial institutions are just one kind of service provider. A service provider can also be non-financial in nature. Regardless whether a service provider is a financial institution or a non-financial institution, essentially the same process occurs. The only difference between a transaction involving a financial institution and a transaction involving a non-financial institution is that the messages may include different data fields.

10 When an EC holder signs up with one of the service providers, the service provider creates a dedicated entry on the EC. Each entry contains the account information for the service provider, the SP's public key, access control information, and other related data. Each EC can support a predetermined number (e.g. ten) of such entries and each such entry is a representation of one service provider.

15 By using the public/private key cryptography, the key distribution process is much simplified. The EC holder him/her/self or any trusted third party such as a bank branch or even a post office can perform the task. The SP's public key is only used for the initial key exchange between the SP and the cardholder. After the initial key exchange step, the SP assigns a session key, which protects any further message exchange between the cardholder and the SP or between 20 the cardholders' themselves.

25 This hybrid system, which uses both public key/private key cryptography and secret key cryptography (i.e., session key), is in contrast to other secret-key systems in that in the hybrid system, the secret key (i.e., session key) is valid for a single session and is not applicable to other sessions. A session has a determinate length of time. A session may terminate based upon a time period or upon conditions being satisfied.

30 Where a merchant is involved in a transaction, the merchant goes through essentially the same procedures as the EC holder to communicate with the SP. The merchant will first perform a key exchange with the SP and receive a session key. The session key will be used by the merchant for subsequent communication with the SP. The cardholder and the merchant digitally sign each message going to the SP and the SP similarly signs the response message going back to the cardholder and the merchant.

35 In the event that a transaction requires interactions with another certificate-based system, the SP, after authenticating the cardholder and the merchant based on further information exchange after the initial key exchange, can act as a surrogate-certificate for the cardholder and the merchant. In the most extreme case, the SP performs solely this surrogate function and becomes a gateway for the certificate-based system. This type of hierarchy is highly desirable since it reduces the number of trust relationships needed to carry out a transaction among multiple systems. In addition, it eliminates the users' need to carry certificates.

1

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram showing the relationship among the components of a system according to an embodiment of the invention.

Figure 2 shows the flow of the two transaction phases via a network.

Figure 3 is the diagrammatic representation of an EC.

Figure 4 shows the format of the service provider data area. Each service provider's information is allocated an entry in the table and is protected by access conditions.

Figure 5 shows how the digital signatures are used in an embodiment of the invention.

10 Figures 6A through 6Q shows the schematic flow chart of the cryptographic system and method used in an embodiment of the invention in order to conduct electronic transactions via an open telecommunication network, such as the Internet.

Figure 7 through Figure 11 depicts the final format and content of the combined request and response messages in the key exchange phase and the transaction phase.

15 Figure 12 shows a service provider conducting a transaction with participants that have
been arranged in series.

Figure 13 shows a service provider transaction on a network with participants that have been arranged in a hierarchical organization scheme.

20

DETAILED DESCRIPTION

The preferred embodiment of the invention is a cryptographic system and method for electronic transactions by using an electronic card (EC) in the form of a smart card or equivalent software and communicating over a communications network.

25 In the preferred embodiment of the invention, the network is an open network such as the Internet. In alternative embodiments of the invention, other open networks and/or closed networks may be used to establish communication between a service provider and its members. For example, a service provider may use its own proprietary financial network to communicate with its members.

30 Any Internet protocol may be used for Internet connections. Example protocols, which can be used include TCP/IP, UDP, HTTP, and the like.

Communication may also be via a communications network transport service such as the Public Switched Telephone Network (PSTN) using traditional analog telephone service (a.k.a. Plain Old Telephone Service or POTS), or by using a digital communication service such as a T-1, E1 or DS-3 data circuit, Integrated Services Digital Network (ISDN), Digital SubscriberLine (DSL) services, or even using a wireless service, and the like. When implemented using such a service the invention may be implemented independent of a communications protocol (i.e. at an electrical interface layer).

1 Communication may also be via a local area network (LAN) or WideArea Network
(WAN) such as Ethernet, Token Ring, FDDI, ATM or the like. Example protocols, which
can be used include TCP/IP, IPX, OSI, and the like.

5 Other communication links might include an optical connection, a wireless RF modem
connection, a cellular modem connection, a satellite connection, etc.

10 The invention may be employed as long as a communication path can be established
between a service provider and its members. The examples above are intended to illustrate
several examples of the various communications environments in which the invention may be
practiced. As is clear to one ordinarily skilled in the art, the invention is not limited to those
environments detailed above.

15 The EC can take the form of a smart card device or a software package running on a
computer system such as a personal computer (PC). When the EC is implemented on a smart
card, it can be used on a network-ready computer system such as a PC to transact with another
member and/or a selected service provider. It will need a read/write interface device to
communicate with a computer system and some application software such as an Internet browser
20 to interface with the cardholder and the network. If the EC is a software package loaded into a
computer system, then no read/write interface is needed. The exemplary embodiment of the
invention is for the EC to act as an electronic wallet (or cyber wallet) which functions similar
to real wallet. A real wallet can carry credit cards, debit cards, ATM cards, health provider
cards, membership cards, cash, etc. An EC has the digital equivalent of all the above-mentioned
financial and non-financial instruments and enables conducting secure transactions over the
Internet.

25 A service provider member can be a merchant and/or an EC cardholder. A merchant is
a member who is paid by the service provider as a result of a transaction. A member can be both
a merchant and an EC cardholder. A merchant may engage in a transaction with other
cardholders, which results in the merchant being paid by the service provider. A merchant may
also be an EC cardholder and purchase supplies, for example, from a merchant supplier.

30 The cryptographic system may involve communication between a service provider and
any number of service provider members. Thus, communication can be between an EC and an
SP, between a merchant and an SP, between a first EC, a second EC, and an SP, between a first
merchant, a second merchant, and an SP, etc. An EC may communicate directly with a service
provider to inquire about an account balance for example. A merchant may communicate with
35 a service provider only on his own behalf and not on behalf of an EC because, for example, the
merchant wants to know his own account balance with the service provider. Communication
between the SP and its members may follow any permutation of the SP and its members. The
organization of the communication links between the SP and its members may be sequential
and/or hierarchical. Communication between the SP and its members may also be via routers,
which route the messages between the SP and its members.

1 The cryptographic method is a two-phased key-exchange-transaction model. The first
phase is a key exchange phase. The second phase is the transaction phase. In the key exchange
phase, the members exchange keys with the service provider. The members send their keys to
the service provider and the service provider uses the keys to send a session key to the members.
5 The session key protects any further message exchange between the cardholder and the SP or
between the cardholders' themselves. In the transaction phase, either the SP can direct the
transaction or the cardholders themselves may conduct the transaction.

10 Figure 1 is a block diagram showing the relationship among the components of a system
according to an exemplary embodiment of the invention involving a cardholder, a merchant, and
service provider.

15 An EC cardholder 20 can conduct a transaction over a network 50 and communicate with
a merchant either by using an EC read/write device 82 attached to an originating computer 84
or by using EC equivalent software 92 running on an originating computer unit 90.

20 A merchant can conduct a transaction over a network by either using a network-ready
point-of-sale(s) (POS) terminal 40 or by using EC equivalent software running on a merchant
device 70 to conduct an electronic transaction with a selected service provider 60 via a network
50 such as the Internet.

25 Once the access conditions to the card have been satisfied, the cardholder can perform
financial or non-financial transactions with other participants of the system through the network
50. In Figure 1, there are three different scenarios in which a transaction over a network can be
conducted.

30 (1) In a POS transaction (Upper left side of figure 1), the cardholder 20 swipes/inserts an
EC through/into a merchant's EC reader/writer 30 at a merchant's premises. The EC
reader/writer is connected to a network-ready merchant POS terminal 40. The network-
ready merchant POS terminal 40 is a secure tamper-resistant programmable device
comprising an input means such as a keyboard, a display device, a processing unit, and
an EC read/write device 30 (an EC interface device). It is typically a small computer
unit such as a PC equipped with a communication link to an open network. The POS
terminal communicates to the SP via the network 50.

35 (2) (Right side of figure 1) A cardholder can conduct a transaction with other participants
of the system by inserting the EC 20 into a read/write device 82, which is connected to
the cardholder's personal computer 84 which is the originating computer. The
originating computer connects to a network 50 allowing the EC to communicate with
the merchant computer unit 70. The merchant computer unit 70 has EC equivalent
software 72 that enables the merchant to receive the EC generated message and
generates a message combining EC information and merchant information. Then, the
combined message is sent to the SP over a network.

(3) (Bottom side of figure 1) A cardholder can conduct a transaction with other participants

1 of the system by using EC equivalent software 92 on the customer cardholder's personal
computer 90. The transaction begins at the originating computer unit 90, that is, the
cardholder's personal computer. The cardholder conducts the transaction over a
5 network 50 and communicates with the merchant's computer unit 70, which in turn
communicates with the SP 60 over a network 50.

While in the preferred embodiment of the invention, a personal computer is used to hold the
EC equivalent software, in alternative embodiments of the invention other electronic devices can
be used to hold the EC equivalent software.

In the preferred embodiment of the invention, the network used to enable the EC to
10 communicate with the merchant is the same network used to enable the merchant to
communicate with the SP. In another embodiment, the network used to enable the EC to
communicate with the merchant may not be the same network used to enable the merchant to
communicate with the SP. In yet another embodiment, the network used to enable one merchant
15 to communicate with the SP may not be the same as the network used to enable another merchant
to communicate with the SP. In still yet another embodiment, the network used to enable an EC
to communicate to the merchant may not be the same as the network used to enable another EC
to communicate with another merchant. An embodiment may consist of a multiplicity of
networks whereby different parties communicate.

In the preferred embodiment of the invention, a transaction is broken down into two phases:
20 a key exchange phase and a transaction phase. Figure 2 is a specific case, which illustrates the
two-phase key-exchange-transaction model where the SP directs the transaction phase. There is
no direct exchange of sensitive information between participants when the SP directs the
transaction.

The key exchange phase is the same where the transaction phase is among the cardholders
25 themselves and where the SP directs the transaction phase. Where the transaction phase is
among the cardholders themselves, the cardholders use the SP session key to communicate with
each other and conduct a transaction.

Figure 2 demonstrates a financial transaction where the SP directs the transaction phase.
The transaction shown involves three parties: an EC (a transaction originator) 102, a merchant
30 104, and a service provider (SP) 106. The originating party is an EC cardholder who is the
consumer and is represented by the computer unit 102. The computer unit 104 represents the
merchant. The computer unit 106 represents the service provider. An SP is selected by both an
EC and merchant.

Figure 2 demonstrates a financial transaction wherein the process flow is from an EC to a
35 merchant to an SP. The cryptographic method's process flow is not limited to any particular
order between merchants and EC cardholders. Figure 2 is merely an example of a particular
transaction, which flows from EC to merchant to service provider. The process flow can also
go from merchant to EC to service provider. Figure 2 demonstrates how service provider

1 members (in this case, the EC cardholder and the merchant) create, append, and send messages
to a service provider.

5 The ten arrows numbered 1 to 10 in figure 2 show how the messages flow among the three parties during the two transactions phases. Steps 1 through 4 belong to the key exchange phase and steps 5 through 10 belong to the transaction phase. In figure 2, the merchant serves as an intermediary between the EC and SP. In step 1, the key exchange request is formatted by the EC and sent to merchant. In step 2, the merchant combines his own key exchange message with the EC's key exchange message and sends the combination key exchange message to an SP. In step 3, the SP formats a key exchange response for the merchant, formats a key exchange response for the EC, combines the key exchange responses to form a combined key exchange response and sends the combined key exchange response to the merchant. In step 4, the merchant separates the key exchange response for the merchant from the key exchange response for the EC and forwards the EC's key exchange response message back to the EC. Step 4 concludes the main activities in the key exchange phase.

10 The transaction phase begins with step 5. In step 5, the EC formats its transaction request message and sends it to merchant. In step 6, the merchant combines the received transaction request message with his own transaction request message and sends the combination transaction request message to the SP. In step 7, the SP formats a transaction response message for the merchant, formats a transaction response message for the EC, combines the transaction response messages and sends the combined transaction response message back to merchant. In step 8, the merchant separates the transaction response message for the merchant from the transaction response message for the EC and forwards the EC's transaction response message back to the EC. In step 9, the EC formats a confirmation message and sends it to the merchant. In step 10, the merchant combines the received confirmation message with his own confirmation message and sends the combination confirmation message the SP. Step 10 concludes the transaction phase of a transaction.

15 While figure 2 demonstrates a simple transaction, some transactions may involve multiple messages. During some transactions, more than one message may be required to complete each phase, in which case, those messages will follow the same rules of combination and flow pattern.
20 For example, during the transaction phase, the SP may require that the EC and the merchant send over account information first. If the account information is verified to be valid, the SP sends confirmation of the account information in the response message. Once the merchant and the EC receives the response message, then the EC and the merchant send the transaction amount and other transaction related information in the next message going to the SP. The SP subsequently approves or disapproves the transaction. The steps in figure 2 apply to both the account message and the transaction message.

25 If the completion of a transaction requires interaction with some external system such as a public key and digital certificate based system 108, the SP will act as a surrogate-certificate

1 for the EC and the merchant and deal with the external system on behalf of the EC and the
merchant. A desired result of the invention is to shield all of the participants of a transaction
from an external system and therefore reduce the number of trust relationships needed to
complete a transaction. If a participant of a transaction has dual membership of this system and
5 an external system, then he has a choice of either acting as a member of this system or as a
member of an external system. In the latter case, the SP will interface with the participants using
the rules of an external system. For example, to deal with an external public and digital
certificate or credential based system, the SP has in its possession all of the required certificate(s)
10 or credential(s) which satisfies the trust relationship demanded by the external system. Such
credentials are required in order for the SP and the external system to complete the transaction
initiated by the EC and the merchant. In this case, only the SP needs to have a trust relationship
with the external system. Based on this trust relationship, individual ECs and merchants are able
15 to complete transactions with the hypothetical external system.

Figure 3 is a diagrammatic representation of a preferred embodiment of an EC. In a
15 preferred embodiment of the invention, an EC is internally composed of the software/hardware
components shown in Figure 3. The EC is ISO 7816-based and supports the same kind of
communication protocols and commands as defined in ISO 7816.

The EC has a card operating system 550 to manage the EC's internal resources. The on-
card cryptographic service 650 can be implemented in software or be provided by a
20 cryptographic co-processor (not shown in figure 3), or other hardware solutions, or a hybrid of
software and hardware.

One of the unique features of the EC is the service provider data area (SPDA) in the EC
memory, which contains the service providers' account and key information. The service
provider data area (SPDA) 700 contains a number of slots. In the preferred embodiment, the
25 SPDA contains a pre-defined number (e.g. ten) of slots -- one for each potential service provider.
In another embodiment, the number of slots may be dynamically changed. A record for each
service provider can be placed into an empty slot. Each record contains the account number,
public key, and other related information for a specific service provider.

Depending on the EC design, the SPDA can optionally allow each SP to include some
30 software (such as an "applet" in the JAVA terminology) to manage its own on-card data and
provide an interface between the SP card data and the host application. In other words, the SPDA
can contain more than just simple data; it can allow each SP to put a self-contained application
program (such as an applet) on the EC to provide its own unique service to the cardholder. The
advantage of this type of design is that the EC itself is now detached from the type of service it
35 can provide. Each SP can bring with it its own service capability. When another SP replaces
an on-card SP, there will be no change necessary to the EC platform. The new SP applet is
simply loaded into the card and it will perform what it is designed to do.

In the SPDA, each service provider is allocated space for public keys. In many transactions,

1 only one key pair is used, but for some online transactions, two or more key pairs are required. If the SP uses the same public/private key pair for both the incoming and the signing of outgoing messages, then one public key is enough. If the SP uses a different key pair for signing, then both SP public keys (one for incoming messages and one for the signing of outgoing messages) 5 are required in the SPDA.

In the preferred embodiment of the invention, two public/private key pairs rather than one public/private key pair is used to communicate with other applications through a network because using two public/private key pairs rather than one public/private key pair provides greater security. One pair is used for decrypting an incoming message, i.e., the sender encrypts 10 the message using the recipient's public key and the recipient decrypts the message using the corresponding private key. The other pair is for the sender to digitally sign the message he sends out and the recipient to verify the digital signature using the corresponding sender's public key.

Each service provider is allocated space for the number of public keys used by the service provider. If the SP uses the same public/private key pair for both incoming messages and 15 signing of outgoing messages, then one public key is enough. If the SP uses different key pairs for receiving and signing messages, then both of the SP's public keys are required in the SPDA.

In an alternative embodiment of the invention, more than two public/private key pairs may be required and used by a service provider for even greater security.

When an EC holder is issued a new financial or non-financial instrument, the issuing 20 institution or a trusted third party will load the needed information comprising a record into an available slot. The information in the slot can be erased when the service provider account is closed. Some of the information in a slot can be read and modified during a transaction, e.g. an account balance. Some information such as account number is write protected, but can be read. Some information such as a private key is both read and write protected. The access conditions 25 600 contain security information such as PINs, biometric data, etc., that an EC user must submit to open the card for use or to gain access to the information stored on the card.

Traditional Personal Identification Numbers (PINs) or other security measures such as 30 biometrics data are used to protect the EC. Biometrics involves the measurement of a cardholder's biological traits, such as physical traits and behavioral traits. A biometric system may measure an individual's fingerprints, hand-geometry, hand writing, facial appearance, speech, physical movements, keyboard typing rhythms, eye features, breath, body odor, DNA, or any other physical attribute of the cardholder. The functions provided by an EC can be activated only after all the access conditions have been satisfied. Each service provider residing 35 on the card can optionally implement other access conditions.

Figure 4 shows the format of the service provider data area of a preferred embodiment of the invention. Each service provider's information is allocated an entry in the table, which can be protected by additional access conditions. The PIN 712 and the miscellaneous data field 714 allows the service provider to provide extra protection or data field to the instrument it supports.

1 The name field 702 contains the names of the service providers, which can be used by the
cardholder at the beginning of an online transaction to initially select the applicable service
provider for a transaction. The key type field 704 specifies the type of key the service provider
chooses to use, secret key, public key, etc. The key value 706 and account information fields
5 708 contain information unique to each service provider. The card type field 710 specifies the
type of instrument a service provider supports.

In the preferred embodiment of the invention, the on-card Operating System (COS)
provides some fundamental services for the cardholder. Following is a list of general functions
which can be performed by the COS:

- 10 (1) Traditional OS functionality such as Memory management, task management, etc
 (2) External communication-read/write of user data and communication protocol handling.
 (3) Loading and updating of on-card cardholder information.
 (4) User PIN changes.
15 (5) Service Provider Data Area management-such as loading and updating of individual service
 provider information, SPDA access control, etc.

The COS will also provide support during various stages of a transaction. For example, the
COS can handle the SP selection at the beginning of a transaction and record the transaction into
20 a log file when the transaction has been completed. An embodiment of the invention may
implement one of the following two design approaches to the COS or a hybrid of the two design
approaches:

- 25 (1) Most of the intelligence can be put into the COS whereby the COS supports most of the EC
 functionalities. Consequently, each on-card service provider area relies on the COS to carry
 out the transaction with the merchant and the SP. In this approach, the COS can provide
 a uniform interface with the outside world for all on-card SPs and efficiently carries out the
 transaction once a SP has been selected.
30 (2) Alternatively, the COS can be a pool of general services each on-card SP can utilize. Each
 SP data area can contain applets, which have the intelligence to carry out a transaction with
 the merchant and the SP. In this approach, the SP has more opportunity to implement its
 own unique feature when performing a transaction.

Figure 5 shows how digital signatures are used in the preferred embodiment of the
invention. A sender of a message first prepares and sends the data portion of a message M 900
35 through a one way hash algorithm, H(*) 902. The output from the hash algorithm is called the
message digest MD of message M 903. The MD is then encrypted, E(*) 904, i.e. digitally signed,
using the sender's private key (Pri). The result is called the digital signature DS of a message M.
The DS is then combined with the original message M 900 and forms a complete message 906
ready for transmission to a recipient through a network 50.

1 The public-key encryption/decryption function can be any of a number of
5 encryption/decryption functions. RSA, which takes its name from the first initials of RSA
developers' last names (Ronald Rivest, Adi Shamir, and Len Adelman), is just one example of
5 a public-key encryption/decryption method, which can be used in an embodiment of the
invention.

10 When the intended recipient receives the message from a network 50, he first separates the
data portion of the message M 900 from the digital signature 912 combined with it. The
recipient then runs the data portion of the message M 900 through the same hash algorithm 910
that was used to encode the data portion of message M 900, and consequently obtains a message
15 digest MD[^] 911 of M. The recipient then decrypts D(*) 908 using the EC's public key, the
digital signature 912 contained in the original message using the sender's public key and
recovers the original message digest, denoted here as MD 909. MD 909 is compared with the
new calculated MD[^] 911 for correctness. If they are not identical, the original message has been
corrupted and should be rejected.

15 Following is a list of symbols and abbreviations used in the figures 5 through 11:
Acknowledegement Data_{EC} = A part of the message sent back by the EC to the SP. It notifies the
SP that the previous message has been successfully received and processed.
Acknowledegement Data_M = A part of the message sent back by the merchant to the SP. It
20 notifies the SP that the previous message has been successfully received and processed.
AI_{EC} = Account information of EC holder.
AI_M = Account information of merchant.
CRYPTO = Cryptogram
D = Decryption function
25 D_{SP-Private-Key} = Decryption using SP's private key.
DS = Digital signature function.
DS_{EC-Private-Key} = Digital signature signed by the EC on a message.
DS_{M-Private-Key} = Digital signature signed by the merchant on a message.
DS_{SP-Private-Key} = Digital signature signed by the SP on a message.
30 E = Encryption function.
E (Data) = Encryption of data under a data encryption key.
E_{SP-PK}, E_{SP-Public-Key} = Data encrypted by SP public key
E_{Skey-EC}, D_{Skey-EC} = Encryption/Decryption using the session key that the SP generated for the EC.
E_{Skey-M}, D_{Skey-M} = Encryption/Decryption using the session key that the SP generated for the
35 merchant.
EC = Electronic card, or electronic card equivalent software
H (M) = Apply a one-way hashing algorithm on M. It generates the message digest (MD) of M.
KE = Key exchange phase.

- 1 M = Merchant
MD = Message Digest
MD[^] = Message Digest produced by message recipient using the message just received as input data.
5 MD_{EC} = The message digest of a message going from EC to SP.
MD_M = The message digest of a message going from merchant to SP.
MD_{SP-M} = The message digest of a message going from SP to merchant.
MD_{SP-EC} = The message digest of a message going from SP to EC which is bypassed by merchant.
10 PLAIN TEXT: Transaction data, which can be transmitted without encryption. Plain text can be different for different messages and transaction parties.
PLAIN TEXT_{EC} = Part of the transaction data provided by EC in its outgoing messages. Plain text data fields are not security sensitive. Therefore, they are transmitted without encryption. Note that the content of this symbol can be different when used in a different message.
15 PLAIN TEXT_M = Part of the transaction data provided by merchant in its outgoing messages. Plain text data fields are not security sensitive. Therefore, they are transmitted without encryption. Note that the content of this symbol can be different when used in a different message.
PLAIN TEXT_{SP-EC} = Part of the transaction data provided by SP for EC only in its outgoing messages. Plain text data fields are not security sensitive. Therefore, they are transmitted without encryption. Note that the content of this symbol can be different when used in a different message.
20 PLAIN TEXT_{SP-M} = Part of the transaction data provided by SP for merchant only in its outgoing messages. Plain text data fields are not security sensitive. Therefore, they are transmitted without encryption. Note that the content of this symbol can be different when used in a different message.
25 STD = Sensitive transaction data, which requires encryption during data transmission.
STD_{EC} = Sensitive transaction digital data provided by EC in its outgoing messages. Note that the content of this symbol can be different when used in a different message.
STD_M = Sensitive transaction digital data provided by merchant in its outgoing messages. Note that the content of this symbol can be different when used in a different message.
30 PK = Public key
EC-PK, PK_{EC} = Public key of the electronic card.
M-PK, PK_M = Public key of the merchant.
35 SP-PK, PK_{SP} = Public key of the selected service provider.
Response Data_{SP-EC} = A part of the message sent back by the SP to the EC during the transaction phase of a transaction. It can include approval/disapproval data and/or any other relevant data.
Response Data_{SP-M} = A part of the message sent back by the SP to the merchant during the

transaction phase of a transaction. It can include approval/disapproval data and/or any other relevant data.

RN = Random number.

RN_{rc} = Random number generated by the EC and is sent to SP.

5 RN_{SP-EC} = Random number generated by the SP and is sent to EC.

RN_i = Random number generated by the merchant.

$RN_{SP,M}$ = Random number generated by the SP and is sent to M.

SP = Financial or non-financial service provider

TA = Transaction (currency) amount.

10 Transaction Identification Number_{SP-EC}, TID_{SP-EC} (Transaction ID_{SP-EC}) = A data field whose value is assigned by the SP during the key exchange phase of a transaction. The EC will use this value to communicate with the SP during the same transaction.

15 Transaction Identification Number_{SP-M}, TID_{SP-M} (Transaction ID_{SP-M}) = A data field whose value
is assigned by the SP during the key exchange phase of a transaction. The merchant will use this
value to communicate with the SP during the same transaction.

* = Combine or concatenation of data within an encryption E or a decryption D.

Figures 6A through 6Q comprise the flowchart for a preferred embodiment of the cryptographic system and method. For the purpose of simplifying the description and symbolism contained in figures 6A through 6Q, the flowchart assumes that each of the parties involved in the transaction uses one key pair. In another embodiment of the invention, two public key pairs may be used, in which case, both public keys need to be exchanged.

The preferred embodiment of the invention consists of two distinct phases: the key exchange phase and the transaction phase.

25 PHASE I: KEY EXCHANGE PHASE (HANDSHAKE PHASE)

The EC cardholder inserts the EC into a card read/write device or starts the EC equivalent software and enters a PIN number and/or satisfies the access conditions 110 to use the EC card. The entered security information conditions is compared 112 with the on-card information 114 to verify that user is authorized to use the EC. If the security information does not match the card security information, then the request to use the card is rejected 116. Otherwise, the card is unlocked 118 for use. Once the card is unlocked, the user can request the list of the on-card SPs available for selection and make a selection 120 by issuing an SP selection command to the EC. Once the SP is selected, the EC proceeds to start the key exchange (KE) with the SP. The public key of the selected SP, represented by the symbols SP-PK and PK_{SP} , is obtained from the EC's SPDA and is used to encrypt messages that will be sent to the SP.

The main purpose of the KE is to securely send the cardholder's public key, PK_{EC} 126 and an EC random number, RN_{EC} 124 to the SP. The SP response to the EC is to assign a session key and a transaction ID to the EC, which will be used by the EC to communicate with the SP for the

1 rest of the transaction. To format the KE message, the EC generates a random number, RN_{EC} 124, concatenates it with the EC's public key, PK_{EC} 126, and EC sensitive transaction data STD_{EC} 128 relevant to the transaction and/or required by the SP. The EC encrypts them 122 using the SP's public key, PK_{SP} , retrieved from the SPDA 120. The resulting EC cryptogram, 5 $E_{ES-PK}(RN_{EC} * PK_{EC} * STD_{EC})$, is then combined 130 with the plain text portion of the message, PLAIN $TEXT_{EC}$ 132, if any, to form an EC combination message, PLAIN $TEXT_{EC} * E_{SP-PK}(RN_{EC} * PK_{EC} * STD_{EC})$. The EC's public key PK_{EC} 126 may be placed in the plain text PLAIN $TEXT_{EC}$ instead of being encrypted when forming the EC combination message.

10 Only sensitive data is encrypted. Non-sensitive response data is included in the plain text. Only the SP is able to read the sensitive data. In a multi-party transaction, the SP has full access 15 to the sensitive information of all the participants.

The resulting EC combination message is then sent through a hashing algorithm 134 to form a hash message, which is the EC message digest MD_{EC} . The EC message digest MD_{EC} is 20 digitally signed by the EC 136 using the EC private key 138 to form a digitally signed message DS_{EC-Private-Key}. The digitally signed message DS_{EC-Private-Key} is then combined 140 with the EC combination message. The combination of the plain text PLAIN $TEXT_{EC}$, cryptogram CRYPTO_{EC} and the digital signature DS_{EC-Private-Key} is the KE message from the EC and is sent to 25 the merchant 158 through a network. Plain text includes all the transaction data fields that are not sensitive in nature and therefore can be transmitted in a clear, discernable form; they do not need to be encrypted. These data fields are different for each message and are defined by the 30 transacting parties.

To communicate with the SP, the merchant goes through essentially the same steps to format its own KE message with the SP as the EC goes through to format the EC's KE message with the merchant. The cardholder and the merchant do not communicate with the SP individually, but through a combined message. Consequently, there will be no need to exchange 25 any confidential financial information between the cardholder and the merchant. The merchant prepares his device for the transaction 142 and selects from his own SPDA, which resides within the merchant's device, the same SP as the EC cardholder has selected for the transaction 144. The public key of the SP, represented by the symbols SP-PK and PK_{SP} , is obtained from the SP's 30 SPDA and is used to encrypt messages that will be sent to the SP.

To format its own KE message, the merchant generates a random number, RN_M 148, concatenates it with the merchant's public key, PK_M 150, and the merchant's sensitive transaction data STD_M . Sensitive transaction data is data that is relevant to the transaction and/or required by the SP 152. The merchant encrypts 146 the combined data using the public key of 35 the service provider, PK_{SP} . The resulting cryptogram is then combined 154 with the plain text portion PLAIN $TEXT_M$ 156 of the message, if any, to form a merchant combination message. The merchant's public key PK_M 150 may be placed within the plain text PLAIN $TEXT_M$ instead of being encrypted when forming the merchant combination message PLAIN $TEXT_M * E_{SP}$.

1 $\text{PK}(\text{RN}_M * \text{PK}_M * \text{STD}_M)$.

The merchant combination message $[\text{PLAIN TEXT}_M * E_{\text{SP-PK}}(\text{RN}_M * \text{PK}_M * \text{STD}_M)]$ is further combined 158 with the EC's KE message $\{[\text{PLAIN TEXT}_{\text{EC}} * E_{\text{SP-PK}}(\text{RN}_{\text{EC}} * \text{PK}_{\text{EC}} * \text{STD}_{\text{EC}})] * DS_{\text{EC-Private-Key}}\}$ to form the data portion of the KE message for both the merchant and the EC, i.e., the EC-merchant combination message $\{[\text{PLAIN TEXT}_{\text{EC}} * E_{\text{SP-PK}}(\text{RN}_{\text{EC}} * \text{PK}_{\text{EC}} * \text{STD}_{\text{EC}})] * DS_{\text{EC-Private-Key}}\} * [\text{PLAIN TEXT}_M * E_{\text{SP-PK}}(\text{RN}_M * \text{PK}_M * \text{STD}_M)]$. The EC-merchant combination message is sent through a hashing algorithm 160 to form a hash message, which is the merchant message digest MD_M . The merchant message digest MD_M is digitally signed 162 by the merchant using the merchant's private key 164 to form a merchant digitally signed message $DS_{M-\text{Private Key}}$. The merchant digitally signed message $DS_{M-\text{Private Key}}$ is then combined 166 with the data portion of the message, i.e., the EC-merchant combination message to form a key exchange request message $<< \{ [\text{PLAIN TEXT}_{\text{EC}} * E_{\text{SP-PK}}(\text{RN}_{\text{EC}} * \text{PK}_{\text{EC}} * \text{STD}_{\text{EC}})] * DS_{\text{EC-Private-Key}} \} * [\text{PLAIN TEXT}_M * E_{\text{SP-PK}}(\text{RN}_M * \text{PK}_M * \text{STD}_M)] >> * DS_{M-\text{Private Key}}$ for both the merchant and EC. This final message is sent to the SP through a network. Figure 7 represents the final format and content of the key exchange request message from a merchant to an SP.

In the preferred embodiment of the invention, the merchant does not check the MD of the EC's request message MD_{EC} because the EC encrypts his public key. However, in an alternate embodiment of the invention, if the EC chooses not to encrypt his public key then the merchant can optionally check the EC's MD before passing it to the SP. In either the case where the EC encrypts his public key or where the EC does not encrypt his public key, for enhanced security and to avoid possible processing errors by the merchant, the SP can still check the EC's MD. When the merchant receives a combination response from the SP for both himself and the EC, the merchant does not have to check the MD for the EC since it is part of the overall message formed by a single originator -- the SP. The merchant only needs to check the MD of the overall message he receives from the SP.

When the SP receives the KE request message, the SP first separates 168 the data portion of the KE request message from the DS and feeds the data portion of the KE request message into a one-way hash algorithm to recalculate the message digest, which becomes MD_M . The SP then separates the merchant's plain text PLAIN TEXT_M , cryptogram CRYPTO_M , digital signature $DS_{M-\text{Private Key}}$ and the EC's KE request message $\text{PLAIN TEXT}_{\text{EC}} * \text{CRYPTO}_{\text{EC}} * DS_{\text{EC-Private-Key}}$. Using its own private key, the SP decrypts merchant's cryptogram 170 and recovers, among other information, the merchant's random number RN_M 148 and the merchant's public key PK_M 150. The SP then uses the recovered PK_M to decrypt the digital signature signed by the merchant $DS_{M-\text{Private Key}}$ and recovers the MD_M for the merchant's KE message. The SP compares 172 the newly hashed MD^{\wedge}_M 168 with the MD_M 170 recovered by decrypting the DS from the original KE message. If there is a discrepancy between MD^{\wedge}_M and MD_M found, then the KE message has been corrupted and is therefore rejected 174. If MD^{\wedge}_M and MD_M match, then the SP separates the data portion of the EC's KE request message from the DS and feeds the data

1 portion of the EC's KE request message into a one-way hash algorithm to recalculate the
message digest (MD_{EC}^*). The SP then separates the EC's plain text $PLAIN\ TEXT_{EC}$ if any,
5 cryptogram $CRYPTO_{EC}$, and digital signature $DS_{EC\text{-Private Key}}$ in the data portion of the EC's KE
request message 176. Using its own private key, the SP decrypts EC's cryptogram and recovers,
among other information, EC's random number RN_{EC} and EC's public key PK_{EC} . The SP then
uses the recovered PK_{EC} to decrypt the digital signature signed by EC and recovers the MD_{EC} for
EC's KE message. In the step 178, SP compares the newly hashed MD_{EC}^* 176 with the MD_{EC} for
EC's KE message. If there is any discrepancy found, the KE message has been corrupted and is therefore rejected 180. Otherwise, SP is ready
10 to send a KE response message back to merchant and EC.

To format the KE response message for the EC, the SP generates a random number, RN_{SP-EC}
184, and a session key $Skey_{EC}$ 186 for the EC, combines them with the EC generated random
number, 188 RN_{EC} , service provider sensitive transaction data STD_{SP-EC} 190 and encrypts them
192 using the EC's public key PK_{EC} . The resulting cryptogram,
15 $E_{EC-PK}(RN_{EC}*RN_{SP-EC}*Skey_{EC}*STD_{SP-EC})$, is combined 196 with a transaction identification
number, TID_{SP-EC} 194 assigned to the EC by the SP and plain text, $PLAIN\ TEXT_{SP-EC}$ 195, if any,
to form the data portion of the response message for the EC. The SP runs this data through a
hash algorithm to calculate the message digest MD_{SP-EC} 198. Using its own private key 202, the
20 SP creates a digital signature $DS_{SP\text{-Private-Key}}$ 200 for the response message by digitally signing the
message digest MD_{SP-EC} . After combining 204 the data portion of the message with the newly
calculated $DS_{SP\text{-Private-Key}}$, the SP's KE response message for the EC is complete,
[$TID_{SP-EC} * PLAIN\ TEXT_{SP-EC} * E_{EC-PK}(RN_{SP-EC} * RN_{EC} * Skey_{EC} * STD_{EC}) * DS_{SP\text{-Private-Key}}$].

To format the KE response message for the merchant, the SP generates a random number
 RN_{SP-M} 208 and a session key $Skey_M$ 210 for the merchant and combines them with the merchant
25 generated random number RN_M 212, sensitive transaction data STD_{SP-EC} 214 and encrypts them
206 using the merchant's public key PK_M recovered in 170. The resulting cryptogram is
combined 216 with a transaction identification number, TID_{SP-M} 218, assigned to the merchant
by the SP and plain text, $PLAIN\ TEXT_{SP-M}$ 220, if any, to form the data portion of the response
message for merchant. The resulting combination message, $TID_{SP-M} * PLAIN\ TEXT_{SP-M} * E_{M-PK}(RN_{SP-M} * RN_M * Skey_M * STD_{SP-M})$ is further combined 222 with the KE response
30 message for the EC, [$TID_{SP-EC} * PLAIN\ TEXT_{SP-EC} * E_{EC-PK}(RN_{SP-EC} * RN_{EC} * Skey_{EC} * STD_{EC}) * DS_{SP\text{-Private-Key}}$], to form the data portion of the SP's final KE response message, [$TID_{SP-EC} * PLAIN\ TEXT_{SP-EC} * E_{EC-PK}(RN_{SP-EC} * RN_{EC} * Skey_{EC} * STD_{EC}) * DS_{SP\text{-Private-Key}} * [TID_{SP-M} * PLAIN\ TEXT_{SP-M} * E_{M-PK}(RN_{SP-M} * RN_M * Skey_M * STD_{SP-M})]$]. The SP runs the data portion through a hash algorithm
35 to calculate the message digest 224. Using its own private key 228, the SP creates a digital
signature, $DS_{SP\text{-Private-Key}}$ 226, for the response message by digitally signing the message digest.
After combining 230 the data portion of the message with the newly calculated $DS_{SP\text{-Private-Key}}$ 226, the KE
response message for both the EC and the merchant is complete. The response message

1 <<{[TID_{SP-EC}*PLAIN TEXT_{SP-EC}*(E_{EC-PK}*RN_{SP-EC}*RN_{EC}*Skey_{EC}*STD_{SP-EC})]*DS_{SP-Private-Key}}*[TID_{SP-M}*PLAIN TEXT_{SP-M}*E_{M-PK}(RN_{SP-M}*RN_M*Skey_M*STD_{SP-M})]>>DS_{SP-Private-Key} is sent
 back to the merchant through a network. Figure 8 depicts the final format and content of the combined KE response message from the SP to the merchant.

5 When the merchant receives the KE response message 232, the merchant first separates the DS_{SP-Private-Key}, which was signed by the SP, and then feeds the data portion of the combined KE response message into a one-way hash algorithm to recalculate the message digest MD[^]_{SP-M}. The merchant then separates the data portion of the SP's KE response message, i.e., TID_{SP-M}, PLAIN TEXT_{SP-M}, CRYPTO_{SP-M}, [(TID_{SP-EC}*PLAIN TEXT_{SP-EC}*CRYPTO_{SP-EC})]*DS_{SP-Private-Key}. The merchant uses SP's public key (selected from 144) to decrypt the digital signature DS_{SP-Private-Key} to recover the message digest MD_{SP-M}. The merchant compares 234 the newly hashed MD[^]_{SP-M} with the MD_{EC}. If there is any discrepancy between MD[^]_{SP-M} and MD_{SP-M}, the KE response message has been corrupted and is therefore rejected 236. If MD[^]_{SP-M} and MD_{SP-M} match, then the merchant identifies the part of the response message which is meant for him and decrypts the 10 cryptogram CRYPTO_{SP-M} 238 using his own private key. The merchant should be able to recover the original random number RN_M (of 148) that he sent to the SP in the KE request message. The merchant compares 240 the recovered random number RN_M (of the step 238) with the original random number RN_M. If they are not equal, then the message has been corrupted 15 and the message is rejected 242. Since the random number RN_M can only be recovered by the merchant using the correct SP private key, it is assured that the sender of the message is indeed the selected SP. The merchant then forwards the EC's KE response message [(TID_{SP-EC}*PLAIN TEXT_{SP-EC}*CRYPTO_{SP-EC})]*DS_{SP-Private-Key} to the EC and prepares for the transaction phase of the 20 transaction.

25 When the EC receives the KE response message 260, the EC first separates the DS_{SP-Private-Key}, which was signed by the SP, and then feeds the data portion of the KE response message for the EC into a one-way hash algorithm producing a MD[^]_{SP-EC}. The EC then separates the data portion of the message, i.e., TID_{SP-EC}, PLAIN TEXT_{SP-EC}, CRYPTO_{SP-EC}, DS_{SP-Private-key}. The EC uses SP's public key (selected in 120) to decrypt the digital signature DS_{SP-Private-key} message and recovers the message digest MD_{SP}. The EC compares 262 the newly hashed MD[^]_{SP-EC} (in 260) 30 with the MD_{SP-EC} recovered by decrypting the DS_{SP-Private-key} from the KE response message for EC. If there is any discrepancy between MD[^]_{SP-EC} and MD_{SP-EC} found, the KE response message for the EC has been corrupted and is therefore rejected 264. If MD[^]_{SP-M} and MD_{SP-M} match, the EC identifies the part of the response message which is meant for him and decrypts 266 the cryptogram CRYPTO_{SP-EC}, which is contained in the message, using his own private key. The EC should be able to recover the original random number RN_{EC} (of 124) that was sent in the EC 35 KE request message. The EC compares 268 the recovered random number RN_{EC} (of 266) with the original random number RN_{EC} (of 124). If the random numbers are not equal, then the message has been corrupted and the message is rejected 270. Since only the SP using the correct

1 SP private key can recover the random number RN_{EC} , this serves to ensure that the sender of the message is indeed the selected SP. The EC prepares for the transaction phase of the transaction.

5 There will be a predefined timeout period set in the EC and the merchant. During a transaction, if a response message is not received within a timeout period, the EC and the merchant will consider the transaction aborted and will either retry or start the recovery process.

10 After successful completion of the KE message exchanges, the SP has EC's public key and the merchant's public key. At this point, both the EC and the merchant has a random number, a transaction ID, and a session key from the SP. The EC and the merchant must send the two random numbers recovered from the KE response message back to the SP to complete the key exchange phase of the transaction. This can be done in two ways. The random numbers can be sent back through a confirmation message from both the EC and the merchant. Or the random numbers can be sent back as part of the next message going out from the EC and the merchant to the SP, such as a transaction message. The second method is simpler and is described in phase II below. The random numbers are used only once to ensure the correctness of the key exchange between the SP and merchant, and the SP and EC. Once the session keys and transaction identification number have been established, the random number are no longer be used.

PHASE II: TRANSACTION PHASE

20 During the transaction phase, the merchant and the EC each sends their own account information such as an account number and other transaction related data such as transaction amount, request for approval or other processing, to the SP. Again, the EC and the merchant talk to the SP individually but through combined messages and the merchant is responsible for combining the messages and sending them as one message to the SP.

25 The EC first forms the transaction message by concatenating the random number RN_{SP-EC} 274 from the SP and the EC's account information with the selected SP, AI_{EC} 276, transaction amount TA 280 and any other sensitive data 278 relevant to the transaction and/or required by the SP. The EC encrypts 272 them using the session key $Skey_{EC}$ assigned by the SP. The $Skey_{EC}$ is a secret key and uses a cryptographic algorithm different from the cryptographic algorithm used for the public key encryption. The resulting cryptogram $CRYPTO_{EC}$, i.e., $Skey_{EC}(RN_{SP-EC} * STD_{EC} * AI_{EC} * TA)$, is then combined 282 with the transaction ID TID_{SP-EC} 284 and the plain text $PLAIN TEXT_{EC}$ 286, if any, to form the data portion of the EC's transaction message, $TID_{SP-EC} * PLAIN TEXT_{EC} * CRYPTO_{EC}$. The data portion 282 is fed into a one-way hash algorithm 288 to calculate the message digest MD_{EC} and the MD_{EC} is then digitally signed 290 by the EC's private key 292. The resulting digital signature 290 is combined with the data portion of the message (from 282) 294 to form EC's transaction request message and then sent to the merchant, $[TID_{SP-EC} * PLAIN TEXT_{EC} * Skey_{EC}(RN_{SP-EC} * STD_{EC} * AI_{EC} * TA)] * DS_{EC-Private-Key}$.

30 The merchant goes through essentially the same steps to form his transaction message. The merchant forms his transaction message by concatenating 246 the RN_{SP-M} from the SP and the

1 merchant's account information with the selected SP, AI_M 248, transaction amount TA 252 and
any other sensitive data STD_M 250 relevant to the transaction and/or required by the SP. The
merchant encrypts them 244 using the session key Skey_M assigned by the SP. The session key
Skey_M is a secret key and is created using a different cryptographic algorithm, such as DES, from
5 the cryptographic algorithm used for public key encryption. The session key Skey_M is used to
perform the encryption at this point to create the cryptogram CRYPTO_M. The resulting
cryptogram CRYPTO_M, i.e., Skey_M(RN_{SP-M}*STD_M*AI_M*TA), is then combined 254 with the
transaction ID TID_{SP-M} 256 and the plain text PLAIN TEXT_M 258, if any, to form the data portion
10 of the merchant's transaction message, TID_{SP-M}*PLAIN TEXT_M*CRYPTO_M. This data is
combined 296 with the EC's transaction request to form the data portion of the final transaction
request message for the SP, [TID_{SP-EC}*PLAIN TEXT_{EC}*Skey_{EC}(RN_{SP-EC}
15 *STD_{EC}*AI_{EC}*TA)]*DS_{EC-Private-Key}*[TID_{SP-M}*PLAIN TEXT_M*Skey_M(RN_{SP-M}*STD_M*AI_M*TA)]. As before, the merchant feeds his combined data through a one-way hash algorithm 298 to
calculate the message digest MD_M and the MD_M is then digitally signed 300 by the merchant's
15 private key 302. The resulting digital signature DS_{M-Private-Key} 300 is combined 304 with the data
portion of the message (from 296) to form the final transaction request message and is then sent
to the SP, {[TID_{SP-EC}*PLAIN TEXT_{EC}*Skey_{EC}(RN_{SP-EC}*STD_{EC}*AI_{EC}*TA)]*DS_{EC-Private-Key}*[TID_{SP-M}
20 *PLAIN TEXT_M*Skey_M(RN_{SP-M}*STD_M*AI_M*TA)]}*DS_{M-Private-Key}. Figure 9 depicts the final
format of the transaction request message.

When the SP receives the transaction request message, the SP first checks 306 the two transaction identification numbers, i.e., TID_{SP-EC} and TID_{SP-M}, sent by the EC and the merchant and makes sure they are valid. When either TID_{SP-M} (of 210) or TID_{SP-EC} (of 186) is found invalid 306, then the message is rejected 308. If the transaction identification numbers are both valid, then the SP proceeds to separate the DS_{M-Private-Key} from the data portion of the message and feeds 25 the data portion of the message, {[TID_{SP-EC}*PLAIN TEXT_{EC}*Skey_{EC}(RN_{SP-EC}
*STD_{EC}*AI_{EC}*TA)]*DS_{EC-Private-Key}*[TID_{SP-M}*PLAIN TEXT_M*Skey_M(RN_{SP-M}
*STD_M*AI_M*TA)]} into a one-way hash algorithm to calculate the message digest MD[^]_M of this message. The SP separates the data portion of the message, i.e., TID_{SP-M}, PLAIN TEXT_M, CRYPTO_M, DS_{M-Private-Key}, (TID_{SP-EC}*PLAIN TEXT_{EC}*CRYPTO_{EC})*DS_{EC-Private-Key}. The 30 SP decrypts 310 the DS_{M-Private-Key} using the merchant's public key and compares the newly recovered message digest MD_M with the message digest just calculated MD[^]_M (from 306). If MD[^]_M and MD_M are not equal, the message has been corrupted and is rejected 314. If MD[^]_M and MD_M match, then the SP decrypts 316 the encrypted portion of the message using the session key Skey_M (of 210) it assigned to the merchant during the KE phase and recovers the data fields 35 contained in the encrypted portion. The SP compares 318 the random number RN_{SP-M} the merchant sends back in the message with the message the SP sent to the merchant originally, RN_{SP-M} (from 208). If the random numbers are not equal, then the merchant has failed the mutual authentication test and the message is rejected 320.

1 In addition, the SP will verify the EC's account information AI_{EC} and the transaction data such as the transaction amount TA. The message is rejected 320 if the AI is no longer valid. It is also rejected when the TA from the EC and the TA from the merchant do not match. There may be other conditions for invalidating a message. If the account information AI_{EC} and the transaction are valid, then the SP goes on to verify the EC portion of the message.
5

As with the merchant's message, the SP first separates 322 the $DS_{EC\text{-Private-Key}}$ from the EC's message and feeds the data portion of the EC's message, ($TID_{SP\text{-}EC} * PLAIN\ TEXT_{EC} * CRYPTO_{EC}$) into a one-way hash algorithm to calculate the message digest MD^{\wedge}_{EC} of the EC message. The SP separates the data portion of EC's transaction request, $TID_{SP\text{-}EC}$, $PLAIN\ TEXT_{EC}$, $CRYPTO_{EC}$,
10 $DS_{EC\text{-Private-Key}}$. The SP decrypts 324 $DS_{EC\text{-Private-Key}}$ using EC's public key PK_{EC} and recovers MD_{EC} . The SP compares 326 the recovered MD_{EC} with MD^{\wedge}_{EC} . If MD^{\wedge}_{EC} and MD_{EC} are not equal, the message has been corrupted and is rejected 328. If MD^{\wedge}_{EC} and MD_{EC} match, then the SP decrypts 330 the encrypted portion of the EC message using the session key $Skey_{EC}$ (of 186) it assigned to the EC during the KE phase and recovers the data fields contained in it. The SP
15 compares 332 the random number $RN_{SP\text{-}EC}$ the EC sends back in the message with the random number $RN_{SP\text{-}EC}$ it sent out to the EC originally (in 184). If the random numbers are not equal, then the EC has failed the mutual authentication test and the message is rejected 334. The SP will verify the merchant's account information AI_M and the transaction data such as the transaction amount TA and will reject the message when the account information is invalid or
20 when the transaction data does not meet the SP's criterion 334. Once the integrity and authenticity of the overall message has been established, the SP can process the data contained in the message and send a response message back. The random number that is sent back in this message completes the mutual authentication between the SP and the merchant, and between the SP and the EC. After this message, no exchange of random numbers will be necessary. The SP
25 can choose to use the random number as the transaction identification number which the merchant and the EC will use in all subsequent messages that they send to the SP.

As before, the response message contains information for both the EC and the merchant. To format the transaction response message for the EC, the SP generates the response data for the EC, $Response\ Data_{SP\text{-}EC}$ 338, and encrypts 336 it using the session key $Skey_{EC}$ assigned to the EC. Only sensitive data is encrypted. Non-sensitive response data is included in the plain text. The cryptogram $CRYPTO_{SP\text{-}EC}$, i.e., $E_{Skey\text{-}EC}(Response\ Data_{SP\text{-}EC})$, is combined 340 with the transaction identification number $TID_{SP\text{-}EC}$ 342 that the SP assigned to the EC (from 194) and the plain text that the SP has for EC 344, if any, to form the data portion of the response message for the EC, i.e., $TID_{SP\text{-}EC} * PLAIN\ TEXT_{SP\text{-}EC} * E_{Skey\text{-}EC}(Response\ Data_{SP\text{-}EC})$. The data portion of the message is fed into a hash algorithm 346 to generate a $MD_{SP\text{-}EC}$ which is digitally signed 348 by the SP using the SP's private key 350. The $DS_{SP\text{-Private-Key}}$ is combined 352 with the data portion of the response message (from 340) to form the complete response message for the EC, $[TID_{SP\text{-}EC} * PLAIN\ TEXT_{SP\text{-}EC} * E_{Skey\text{-}EC}(Response\ Data_{SP\text{-}EC})] * DS_{SP\text{-Private-Key}}$.

1 To format the transaction response message for the merchant, the SP generates the response
 data for the merchant, Response Data_{SP-M} 356, and encrypts 354 it using the session key Skey_M
 assigned to the merchant (from 210). The cryptogram CRYPTO_{SP-M}, is combined 358 with the
 transaction identification number TID_{SP-M} assigned to merchant 360 (from 218) and the plain text
 5 PLAIN TEXT_{SP-M} that the SP has for merchant 362, if any, to form the data portion of the
 response message for the merchant, TID_{SP-M}*PLAIN TEXT_{SP-M}*CRYPTO_{SP-M}. The data is then
 combined 364 with the completed response message for the EC to form the data portion of the
 response message for both the EC and the merchant, [(TID_{SP-EC}*PLAIN TEXT_{SP-EC}*E_{Skey-EC}(Response Data_{SP-EC})]*DS_{SP-Private-Key}*[TID_{SP-M}*PLAIN TEXT_{SP-M}*E_{Skey-M}(Response Data_{SP-M})].
 10

The data is then fed into a hash algorithm 366 to generate a MD_{SP-M} which is digitally signed
 368 by the SP using the SP's private key 370. The DS_{SP-Private-Key} is combined 372 with the data
 portion of the response message for both the EC and the merchant to form the complete response
 15 message for both the EC and the merchant, <<{[TID_{SP-EC}*PLAIN TEXT_{SP-EC}*E_{Skey-EC}(Response Data_{SP-EC})]*DS_{SP-Private-Key}*[TID_{SP-M}*PLAIN TEXT_{SP-M}*E_{Skey-M}(Response Data_{SP-M})]>> DS_{SP-Private-Key}. The SP then sends its response message back to the merchant. Figure 10 depicts the final
 format of the transaction response message.

When the merchant receives the message, the merchant first checks 374 the transaction
 identification number, TID_{SP-M}, in the message and makes sure it is valid. If the transaction
 20 identification number is invalid then the message is rejected 376. If the TID_{SP-M} is valid, then
 the merchant separates the DS_{SP-Private-Key} which was signed by the SP from the data portion of the
 message, and then feeds the data portion of the transaction response message <<{[TID_{SP-EC}*PLAIN TEXT_{SP-EC}*E_{Skey-EC}(Response Data_{SP-EC})]*DS_{SP-Private-Key}*[TID_{SP-M}*PLAIN TEXT_{SP-M}*E_{Skey-M}(Response Data_{SP-M})]>> into a one-way hash algorithm producing a MD_{SP-M}. The
 25 merchant separates the data portion of the message into different parts, TID_{SP-M}, PLAIN
 TEXT_{SP-M}, CRYPTO_{SP-M}, DS_{SP-Private-Key} (TID_{SP-EC}*PLAIN TEXT_{SP-EC}*CRYPTO_{SP-EC}*DS_{SP-Private-Key}) and prepares to forward SP's transaction response message to the EC. The merchant
 decrypts 378 the encrypted portion of the SP's message using the session key Skey_M assigned
 30 by the SP during the KE phase and recovers the data fields contained within it. The merchant
 then uses SP's public key, PK_{SP} (from 144), to decrypt the digital signature DS_{SP-Private-Key} to
 recover MD_{SP-M}. The merchant compares 380 the newly hashed MD[^]_{SP-M} (from 374) with the
 recovered MD_{SP-M}. If MD[^]_{SP-M} and MD_{SP-M} do not match, then the transaction response message
 35 has been corrupted and is therefore rejected 382. If the message digests match, then the
 merchant starts processing the message. As usual, the EC portion of the transaction response
 message (TID_{SP-EC}*PLAIN TEXT_{SP-EC}*CRYPTO_{SP-EC}*DS_{SP-Private-Key}) is passed to EC.

When the EC receives the transaction response message, the EC first checks 394 the
 transaction identification number, TID_{SP-EC}, in the message and makes sure it is valid. If the
 transaction identification numbers is invalid, then the message is rejected 396. If the transaction

1 identification number is valid, then the merchant separates the $DS_{SP\text{-}Private\text{-}Key}$ which was signed
by the SP, from the data portion of the transaction response message, and then feeds the data
portion of the EC transaction response message $TID_{SP\text{-}EC} * PLAIN\ TEXT_{SP\text{-}EC} * Skey_{EC}(Response\ Data_{SP\text{-}EC})$ into a one-way hash algorithm producing $MD^{\wedge}_{SP\text{-}EC}$. The EC separates the message
5 into different parts, $TID_{SP\text{-}EC}$, $PLAIN\ TEXT_{SP\text{-}EC}$, $CRYPTO_{SP\text{-}EC}$, $DS_{SP\text{-}Private\text{-}Key}$. The EC decrypts 398
the encrypted portion of SP's message using the session key Skey assigned by the SP during the
KE phase and recovers the data fields contained within it. The EC uses SP's public key (from
120) to decrypt the digital signature $DS_{SP\text{-}Private\text{-}Key}$ and recovers the message digest $MD_{SP\text{-}EC}$. The
merchant compares 400 the newly hashed $MD^{\wedge}_{SP\text{-}EC}$ 394 with the recovered $MD_{SP\text{-}EC}$. If $MD^{\wedge}_{SP\text{-}EC}$
10 and $MD_{SP\text{-}EC}$ do not match, then the transaction response message has been corrupted and is
therefore rejected 402. If the message digests match, then the EC starts processing the message.

At the end of the transaction, the EC and the merchant can, if required by the SP, send an acknowledgement message to the SP to signal that the response message has been correctly received and processed. This acknowledgement data can be included as a part of the next
15 message to be sent to the SP, if there are more messages to be exchanged between the SP and the merchant and the EC before the transaction ends. Or the acknowledgement data can be a message by itself.

To format the acknowledgement message, the EC first encrypts 404 the sensitive part of the acknowledgement data, $Acknowledgement\ Data_{EC}$, 406, if any, using the session key, $Skey_{EC}$ thus creating $Skey_{EC}(Acknowledgement\ Data_{EC})$. The EC combines 408 the resulting cryptogram with the transaction identification number $TID_{SP\text{-}EC}$ 410 assigned by the SP and the plain text $PLAIN\ TEXT_{EC}$ 412, if any. This forms the data portion of EC's acknowledgement message, $TID_{SP\text{-}EC} * PLAIN\ TEXT_{EC} * Skey_{EC}(Acknowledgement\ Data_{EC})$. This combined data is then fed into a one-way hash algorithm 414 to generate the MD_{EC} . The resulting MD_{EC} is then digitally
25 signed 416 by the EC using the EC's private key 418 to generate a $DS_{EC\text{-}Private\text{-}Key}$. The $DS_{EC\text{-}Private\text{-}Key}$ is combined 420 with the data portion of the message (from 408) to form the complete acknowledgement message for the EC, $[TID_{SP\text{-}EC} * PLAIN\ TEXT_{EC} * Skey_{EC}(Acknowledgement\ Data_{EC})] * DS_{EC\text{-}Private\text{-}Key}$. The acknowledgement message is then sent to the merchant.

The merchant goes through the same steps to form his own acknowledgement message. To format the acknowledgement message, the merchant first encrypts the sensitive parts of the acknowledgement data, $Acknowledgement\ Data_M$ 386, if any using the session key $Skey_M$ assigned by the SP to merchant, thus creating $Skey_M(RN_{SP\text{-}M} * Acknowledgement\ Data_M)$. The merchant combines 388 the resulting cryptogram with the transaction identification number $TID_{SP\text{-}M}$ 390 assigned by the SP, and the plain text $PLAIN\ TEXT_M$ (from 392), if any. This forms
35 the data portion of the merchant's acknowledgement message, $TID_{SP\text{-}M} * PLAIN\ TEXT_M * Skey_M(RN_{SP\text{-}M} * Acknowledgement\ Data_M)$. This data portion is further combined 422 with the acknowledgement message received from the EC to form the data portion of the combined acknowledgement message for the SP, $\{[TID_{SP\text{-}EC} * PLAIN\ TEXT_{EC} * Skey_{EC}(Acknowledgement\ Data_{EC})] * DS_{EC\text{-}Private\text{-}Key}, [TID_{SP\text{-}M} * PLAIN\ TEXT_M * Skey_M(RN_{SP\text{-}M} * Acknowledgement\ Data_M)]\}$.

1 Data_{EC}]) * DS_{EC-Private-Key}} *[TID_{SP-M} * PLAIN TEXT_M * Skey_M(Acknowledgement Data_M)]. The merchant feeds the data portion of the combined acknowledgement message for the SP into a one-way hash algorithm to generate the message digest MD_M. The resulting MD_M is then digitally signed by the merchant using the merchant's private key 428 to generate DS_{M-Private-Key}
5 426. The DS_{M-Private-Key} is combined 430 with the data portion of the message (from 422) to form the final combined acknowledgement message of the EC and the merchant designated for the SP, <<{[TID_{SP-EC} * PLAIN TEXT_{EC} * Skey_{EC}(Acknowledgement Data_{EC})]* DS_{EC-Private-Key}} *[TID_{SP-M} * PLAIN TEXT_M * Skey_M(Acknowledgement Data_M)]>> * DS_{M-Private-Key}. This message is then sent to the SP. Figure 11 depicts the final format of the transaction acknowledgement message.

10 TID_{SP-M} is the transaction identification number assigned by the SP to the merchant (from 218) and TID_{SP-EC} is the transaction identification number assigned by the SP to the EC (from 194). Upon receiving the transaction acknowledgement message, the SP checks 432 the two transaction identification numbers, TID_{SP-M} and TID_{SP-EC}, sent by the EC and the merchant and makes sure they are valid. When either TID_{SP-M} or TID_{SP-EC} is found invalid, then the message
15 is rejected 434. If the transaction identification numbers are both valid, then the SP proceeds to separate the DS_{M-Private-Key} from the combined acknowledgement message and feeds the data portion of the combined acknowledgement message <<{[TID_{SP-EC} * PLAIN TEXT_{EC} * Skey_{EC}(Acknowledgement Data_{EC})]* DS_{EC-Private-Key}} *[TID_{SP-M} * PLAIN TEXT_M * Skey_M(Acknowledgement Data_M)]>> into a one-way hash algorithm to calculate the message digest MD[^]_M of this message. The SP separates the data portion of the message, TID_{SP-M}, PLAIN TEXT_M, CRYPTO_M, DS_{M-Private-Key}, (TID_{SP-EC} * PLAIN TEXT_{EC} * CRYPTO_{EC}) * DS_{EC}.
20 Private-Key. The SP decrypts 436 the DS_{M-Private-Key} using the merchant's public key PK_M and compares the recovered message digest MD_M 432 with the message digest just calculated MD[^]_M 436. If MD[^]_M and MD_M are not equal, then the message has been corrupted and is rejected 440.
25 If MD[^]_M and MD_M match, then the SP decrypts 442 the encrypted portion of the merchant's acknowledgement message using the session key Skey_M (from 210) that it assigned to the merchant during the KE phase and recovers the acknowledgement data contained within it.

30 The SP separates 444 the DS_{EC-Private-Key} from the EC's acknowledgement message and feeds the data portion of the EC's acknowledgement message, TID_{SP-EC} * PLAIN TEXT_{EC} * CRYPTO_{EC}, into a one-way hash algorithm to calculate the message digest MD[^]_{EC} of this message. The SP separates the data portion of the EC's acknowledgement message, TID_{SP-EC}, PLAIN TEXT_{EC}, CRYPTO_{EC}, DS_{EC-Private-Key}. The SP decrypts 446 the DS_{EC-Private-Key} using the EC's public key PK_{EC} and compares 448 the recovered MD_{EC} with the message digest just calculated MD[^]_{EC} 444. If the message digests are not equal, then the message has been corrupted and is rejected 450.
35 If MD[^]_{EC} and MD_{EC} match, then the SP decrypts 452 the encrypted portion of the message using the session key Skey_{EC} (from 186) that it assigned to the EC during the KE phase and recovers the acknowledgement data contained within it. This completes the processing of the transaction phase of the transaction 454.

1 Throughout the transaction, in a preferred embodiment, the EC works with interface
software provided by Internet browser software such as the Microsoft Explorer or Netscape
Navigator. In a typical session, the cardholder points his browser to the merchant's URL and
orders goods or services from the merchant. At the time of payment, the browser will invoke the
5 EC interface software, which can be built into the browser or included as a plug-in or add-on
software component, and allow the transaction to proceed. The cardholder can point his browser
to the URL of any SP member.

10 The two-phased transaction described in figure 6A-6Q above is just a specific case of
applying the two-phased key-exchange-transaction model. In the two-phased transaction
described in figures 6A-6Q, the number of parties involved in the transaction is three: the EC,
the merchant and the SP. The two-phased key-exchange-transaction model is similarly
applicable to cases where the number of parties involved varies from two to many. In a
transaction that involves more than three parties, there is only one party that plays the role of the
SP. All other parties use the public key of the selected SP to perform the initial key exchange
15 and use session keys and transaction Ids assigned by the SP to carry out the transaction.

20 The two-phased key-exchange-transaction model is applicable to organization schemes
wherein: (1) the participants can be arranged with possible routers in series with the service
provider; or (2) the participants can be arranged with possible routers in a hierarchical
organization. These additional organization schemes may involve routers, which route messages
25 to the next level. A level of a hierarchy may be composed of any number of participants and/or
routers. The next level is the next participant or router that is next in the sequence or hierarchy.
In a hierarchical organization scheme, the next level includes all possible next participants and
routers. For the hierarchical organization scheme, the SP establishes the criterion for
determining the next participant or router to which a message is sent.

30 A router is a gateway/conduit, which collects the messages from a previous level and
performs some processing on the messages according to an SP's requirements such as combining
them, and then forwards the messages to the SP. Each participant need only form his own
message (data and digital signature) and send it to the next level. A participant combines all the
messages he receives with his own message and digitally signs the combined message before
35 sending it to next level. In the hierarchical organization's simplest form, there is only one
message router, which collects messages from all the other participants and sends the combined
message to the SP.

35 In the series organization, an originator of a transaction is in series with routers and/or
participants who in turn are in series with a service provider 60. In the preferred
embodiment of the invention, each element shown in figure 12 is a participant. In an alternative
embodiment of the invention, any intermediate element between the originator and the SP can
be a router.

An originator conducts a transaction with participants 1100, 1120, 1140 and 1160 and a

1 service provider that have been arranged in series as shown in Figure 12. This is similar to the
three-party scenario described in figures 6A-6Q except for the fact that now there is more parties
involved. Note participants 3,4,5,6 ... n-2 that have been arranged in series 1180. Each of the
5 participants prepares his own message, incorporates it with the message he receives from a prior
participant, if any, appends a digital signature with the message, and then sends it to the next
participant in the line. The combined message is eventually sent to the SP and the SP forms the
response message accordingly and sends it back through the same path the original request
message has traveled.

10 Figure 13 shows elements arranged in a hierarchical organization scheme, where each
element, $X_{j,1}$ to $X_{j,n}$ ($n = 1, 2, 3, \dots$) 1200, is a participant of the transaction and not a message
router, and each element, $X_{j,k}$ ($j = 2, 3, 4, \dots; k = 1, 2, 3, \dots m$; m is a variable of type n ; m may
be a different value for different levels of a hierarchy) 1210, can either be a participant or a
router. The upward pointing bold arrow represents sending a request message 1220. The
downward pointing arrow represents sending a response message 1230.

15 Each participant collects messages from a number of participants he is responsible for and,
after combining the messages with his own and forming a new message, sends the new message
to the next level. A hierarchical organization scheme may include only one participant to as
many as is required (The most regressive case of the hierarchical scheme is one participant and
20 one service provider). Eventually, at the last element before the service provider, $X_{o,1}$ where o
is of type n , all messages are combined into one message 1240, which is then sent to the SP 60.
Again, the SP forms the response message and sends it back through the same route.

25 In the case when the SP is not directing the transaction, the members are conducting the
transaction among themselves using the session key generated by the SP. A transaction can
occur between two or more members. When there are more than two members involved in the
transaction, the messages can flow from member to member in any order. A member sends a
transaction request message and receives a transaction response message. A member does not
necessarily have to receive a transaction response message from the same member that he sent
the transaction request message. For example, three members in a transaction can be organized
30 in a ring and send messages around the ring. A first member can send a transaction request
message to a second member who in turn sends a transaction request message and a transaction
response message to third member. The third member sends a transaction request message and
a transaction response message to the first member, and the first member sends a transaction
response message to a second member. A member receiving a transaction request message
creates a transaction response message, which eventually will be sent to the member who sent
35 the transaction request message.

During the key exchange phase, the SP obtains the public keys of all the transaction
participating members. The SP sends to each participating member, the other members' public
keys prior to the participating members conducting a transaction among them. The transaction

1 request messages and the transaction response message include plain text, if any, a cryptogram,
and a digital signature of the sending party.

5 In the case when the SP needs to act as the surrogate-certificate for the EC and/or the merchant in order to deal with a certificate-based external system, the SP shields the EC and/or the merchant from the operation of the external interface. The SP only returns to the EC and/or the merchant, the information needed to complete the transaction with the EC and/or the merchant.

10 While there have been described herein what are considered to be preferred and exemplary embodiments of the present invention, other modifications of the invention shall be apparent to those with ordinary skill in the art. Therefore, it is desired to be secured in the appended claims all such modifications and extensions as fall within the true spirit and scope of the invention. The invention is to be construed as including all embodiments thereof that fall within the scope of the appended claims and the invention should only be limited by the appended claims below. In addition, one with ordinary skill in the art will readily appreciate that other 15 applications may be substituted for those set forth herein without departing from the spirit and scope of the present invention.

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1 CLAIMS:

1. A system for electronic transactions comprising:
 - an electronic card having,
 - a cryptographic service for encryption and decryption,
 - a data area for storing information, and
 - 5 a data area for storing cardholder with the service provider member terminal;
 - a service provider member terminal responsive to the electronic card; and
 - a service provider terminal in communication service provider information.
- 10 2. The system of claim 1 wherein the electronic card is a physical card.
3. The system of claim 1 further comprising software having the electronic card.
- 15 4. The system of claim 1 wherein the electronic card further comprises a card operating system for loading and updating cardholder information, changing a PIN, and managing the service provider data area.
5. The system of claim 1 wherein the electronic card performs external communication read/write operations, and communication protocol handling.
- 20 6. The system of claim 1 wherein the electronic card further comprises software to manage the electronic card.
7. The system of claim 1 wherein the data area for storing service provider information 25 comprises a service provider record comprising:
 - a name field indicating the service provider;
 - a key value; and
 - an account information field containing information unique to each service provider.
- 30 8. The system of claim 1 wherein the electronic card further comprises application software.
9. The system of claim 1 wherein the electronic card further comprises applets.
- 35 10. The system of claim 1 further comprising an external system wherein the service provider terminal communicates with the external system.
11. The system of claim 7 wherein each service provider record further comprises a card type field specifying the type of instrument a service provider supports.

1 12. A method of conducting an electronic transaction using an electronic card comprising the steps of:

generating a session key at the service provider;

exchanging keys by sending a key from a member to a service provider and sending a session

5 key from the service provider to the member; and

using the session key to conduct a transaction.

13. The method of claim 12 wherein the step of exchanging keys comprises the steps of:

sending a key exchange request message from a member to a service provider; and

10 formatting a key exchange response including the session key for a member and sending the key exchange response to a member.

14. The method of claim 12 wherein the step of using a session key to conduct a transaction comprises the steps of:

15 formatting a member transaction request message using the session key and sending it to the service provider; and

formatting at the service provider, a transaction response message for the member and sending the transaction response message to the member.

20 15. The method of claim 12 wherein the step of using a session key to conduct a transaction comprises the steps of:

formatting by a first member, using the session key, a transaction request message, the transaction request message including a digital signature of the first member, and sending the transaction request message to a second member; and

25 formatting by a second member, using the session key, a transaction response message, the transaction response message including a digital signature of the second member, and sending the transaction response message to the first member.

30 16. The method of claim 12 wherein the step of using a session key to conduct a transaction comprises the steps of:

formatting by a first member, using the session key, a transaction request message, the transaction request message including a digital signature of the first member, and sending the transaction request message to an intermediate member; and

35 formatting by an intermediate member, using the session key, a transaction response message, the transaction response message including a digital signature of the intermediate member, and sending the transaction response message to a final member;

formatting by a final member, using the session key, a transaction response message, the transaction response message including a digital signature of the final member, and sending the

1 transaction response message to the first member.

17. The method of claim 12 wherein the step of exchanging keys comprises the steps of:
sending a key exchange request message from the electronic card to a merchant terminal;
5 combining at the merchant terminal, a merchant key exchange request message with the
electronic card's key exchange request message and sending the combined key exchange request
message to a service provider;

formatting a key exchange response including the session key for the merchant terminal,
formatting a key exchange response including the session key for the electronic card, combining
10 the key exchange responses into a combined key exchange response and sending the combined
key exchange response to the merchant terminal; and

separating at the merchant terminal, the key exchange response for the merchant from the key
exchange response for the electronic card system, and forwarding the key exchange response for
the electronic card to the electronic card.

15 18. The method of claim 12 wherein the step of using a session key to conduct a transaction
comprises the steps of:

formatting the electronic card's transaction request message using the session key and
sending it to the merchant terminal;

20 formatting at the merchant's terminal, using the session key, the merchant transaction request
message combining the received transaction request message with the merchant transaction
request message and sending the combined transaction request message to the service provider;

25 formatting by the service provider, using the session key, a transaction response message for
the merchant, a transaction response message for the electronic card system, and combining the
transaction response messages into a combined transaction response message and sending the
combined transaction response message to the merchant terminal; and

separating at the merchant terminal, the transaction response message for the merchant from
the transaction response message for the electronic card, and forwarding the transaction response
message for the electronic card system to the electronic card.

30 19. The method of claim 12 wherein when the service provider is directing the transaction,
only the service provider can read sensitive transaction data within a message sent from a
member.

35 20. The method of claim 12 wherein when the service provider is not directing the
transaction, only the service provider can read sensitive transaction data within a message sent
from a member during the key exchange phase.

- 1 21. The method of claim 13 wherein the key exchange response further comprises public
keys for every member involved in a transaction.
- 5 22. The method of claim 13 wherein a key exchange request message includes a member
generated random number within the encrypted part of the key exchange message.
- 10 23. The method of claim 13 wherein a key exchange request message includes a member
generated digital signature.
- 15 24. The method of claim 13 wherein a key exchange request message from a member
includes a cryptogram comprising:
a random number of the member; and
sensitive data of the member.
- 20 25. The method of claim 14 wherein a transaction message includes a random number within
the encrypted part of the transaction message.
- 25 26. The method of claim 14 wherein a transaction message includes a digital signature of a
sending party.
- 30 27. The method of claim 14 wherein only the service provider can read sensitive transaction
data within a transaction message.
- 35 28. The method of claim 14 further comprising the steps of:
formatting at the member, using the session key, a transaction Acknowledgement message
and sending the transaction Acknowledgement message to the service provider.
- 40 29. The method of claim 18 further comprising the steps of:
formatting at the electronic card, using the session key, a transaction Acknowledgement
message and sending the transaction Acknowledgement message to the merchant; and
formatting at the merchant's terminal, using the session key, the merchant transaction
Acknowledgement message, combining the received transaction Acknowledgement message
with the merchant transaction Acknowledgement message and sending the combined transaction
Acknowledgement message to the service provider.
- 45 30. The method of claim 24 wherein the key exchange request message further comprises
plain text.

1 31. The method of claim 24 wherein the key exchange request message further includes a digital signature of a member.

5 32. The method of claim 24 wherein the cryptogram further comprises a public key of the member.

10 33. The method of claim 25 wherein a transaction message includes a digital signature of a sending party.

15 34. A method of sending a key exchange message comprising the steps of:
satisfying electronic card access conditions by an electronic cardholder;
selecting a service provider by the electronic cardholder;
generating an electronic card random number by the electronic card;
encrypting by the electronic card with a service provider's public key, a random number, an electronic card public key, and electronic card sensitive transaction data to form an electronic card cryptogram;
combining by the electronic card the electronic card cryptogram with plain text, if any, to form an electronic card combination message;
applying a hashing algorithm to the electronic card combination message to form an electronic card message digest;
20 digitally signing by the electronic card, the electronic card message digest using the electronic card private key to form an electronic card digitally signed message;
combining by the electronic card, the electronic card combination message with the electronic card digitally signed message to form a key exchange message from the electronic card; and
25 sending the electronic card key exchange message from the electronic card to a merchant through a network.

30 35. The method of claim 34 further comprising the steps of:
generating a merchant random number by a merchant device;
encrypting by the merchant device with a service provider's (SP's) public key, a merchant random number, a merchant public key, and merchant sensitive data to form a merchant cryptogram;
combining by the merchant device, the merchant cryptogram with plain text, if any, to form a merchant combination message;
35 combining by the merchant device the electronic card (EC) key exchange message with the merchant combination message to form an EC-merchant combination message;
applying a hashing algorithm to the EC-merchant combination message to form a merchant

- 1 message digest;
digitally signing by the merchant device, the merchant message digest using the merchant's
private key to form a merchant digitally signed message;
- 5 combining by the merchant, the EC-merchant combination message with the merchant
digitally signed message to form a merchant key exchange request message from the merchant;
and
- 10 sending the merchant key exchange request message from the merchant to a service provider
through a network.
- 15 36. A key exchange request message comprising:
electronic card plain text;
electronic card cryptogram, encrypted with a service provider public key, comprising an
electronic card random number, an electronic card public key, and electronic card sensitive
transaction data;
- 20 an electronic card digital signature of the electronic card plain text and the electronic card
cryptogram;
merchant plain text;
merchant cryptogram, encrypted with the service provider public key, of a merchant random
number, a merchant public key, and merchant sensitive transaction data; and
a merchant digital signature of the merchant plain text and the merchant cryptogram.
- 25 37. A key exchange response message comprising:
service provider (SP) plain text for the electronic card (EC);
SP transaction identification number for the EC;
SP cryptogram for the EC, encrypted with the EC public key, of the EC random number, an
SP random number for the EC, a session key, and SP sensitive transaction data for the EC;
an SP digital signature of the SP plain text for the EC, the SP transaction identification
number for the EC; and the SP cryptogram for the EC;
- 30 SP plain text for the merchant;
SP transaction identification number for the merchant;
SP cryptogram for the merchant encrypted with the merchant public key, of the merchant
random number, an SP random number for the merchant, a session key, and SP sensitive
transaction data for the merchant; and
an SP digital signature of the SP plain text for the merchant, the SP transaction identification
number for the merchant; and the SP cryptogram for the merchant.
- 35 38. A method of conducting an electronic transaction among multiple parties arranged in
series comprising the steps of:

- 1 sending a key exchange request message from an electronic card to a first party where the
first party is a message router or participant;
- 5 sending the key exchange request message from the first party to a next party if the first party
is a router;
- 5 combining a first party's key exchange request message with the electronic card's key exchange
request message and sending the combined key exchange request message to a next party if the
first party is a participant;
- 10 sending the key exchange request message to a next party if the current party is a message
router;
- 10 combining a current party's key exchange request message with a last party's key exchange
request message and sending the combined key exchange request message to a next party, if the
current party is a participant;
- 15 formatting, by the service provider, into one message, a key exchange response for each
participant and sending the message in reverse order of the path for sending the key exchange
request message to the service provider; and
- 15 separating, by every participant, the key exchange response for itself from the key exchange
responses for the other participants, and forwarding the remaining key exchange responses to the
other participants in reverse order of the path for sending the key exchange request message to
the service provider, until the electronic card receives its key exchange response.
- 20 39. A method of conducting an electronic transaction among multiple parties arranged in
series comprising the steps of:
- 20 sending a transaction request message from an electronic card to a first party where the first
party is a message router or participant;
- 25 sending the transaction request message from the first party to a next party if the first party
is a router;
- 25 combining a first party's transaction request message with the electronic card's transaction
request message and sending the combined transaction request message to a next party if the first
party is a participant;
- 30 sending the transaction request message to a next party if the current party is a message
router;
- 30 combining a current party's transaction request message with a last party's transaction
request message and sending the combined transaction request message to a next party, if the
current party is a participant;
- 35 formatting, by the service provider, into one message, a transaction response for each
participant and sending the message in reverse order of the path for sending the transaction
request message to the service provider; and
- 35 separating, by every participant, the transaction response for itself from the transaction

1 responses for the other participants, and forwarding the remaining transaction responses to the other participants in reverse order of the path for sending the transaction request message to the service provider, until the electronic card receives its transaction response.

5 40. A method of conducting an electronic transaction among multiple parties arranged in a hierarchical organization comprising the steps of:

sending a key exchange request message from an electronic card to a first party where the first party is a message router or participant;

10 sending the key exchange request message to a next party $X_{j,k}$ ($j = 2, 3, 4, \dots$; $k = 1, 2, 3, \dots m$; m is a variable of type n ; $n = 1, 2, 3, \dots$; m can be different values for different values of j) if the first party is a message router;

15 combining a first party's key exchange request message with the electronic card's key exchange request message and sending the combined key exchange request message to a next party $X_{j,k}$ if the first party is a participant;

sending the key exchange request message to the next party $X_{j,k}$ if a current party $X_{j,k}$ is a message router;

20 combining a current party $X_{j,k}$'s key exchange request message with the last party's key exchange request message and sending the combined key exchange request message to the next party $X_{j,k}$, if the current party $X_{j,k}$ is a participant;

25 formatting, by the service provider, into one message, a key exchange response for each participant and sending the message in reverse order of the path for sending the key exchange request message to the service provider; and

separating, by every participant, the key exchange response for itself from the key exchange responses for the other participants, and forwarding the remaining key exchange responses to the other participants in reverse order of the path for sending the key exchange request message to the service provider, until the electronic card receives its key exchange response.

30 41. A method of conducting an electronic transaction among multiple parties arranged in a hierarchical organization comprising the steps of:

sending a transaction request message from an electronic card to a first party where the first party is a message router or participant;

35 sending the transaction request message to a next party $X_{j,k}$ ($j = 2, 3, 4, \dots$; $k = 1, 2, 3, \dots m$; m is a variable of type n ; $n = 1, 2, 3, \dots$; m can be different values for different values of j) if the first party is a message router;

combining a first party's transaction request message with the electronic card's transaction request message and sending the combined transaction request message to a next party $X_{j,k}$ if the first party is a participant;

sending the transaction request message to the next party $X_{j,k}$ if a current party $X_{j,k}$ is a

1 message router;

combining a current party $X_{j,k}$'s transaction request message with the last party's transaction request message and sending the combined transaction request message to the next party $X_{j,k}$, if the current party $X_{j,k}$ is a participant;

5 formatting, by the service provider, into one message, a transaction response for each participant and sending the message in reverse order of the path for sending the transaction request message to the service provider; and

10 separating, by every participant, the transaction response for itself from the transaction responses for the other participants, and forwarding the remaining transaction responses to the other participants in reverse order of the path for sending the transaction request message to the service provider, until the electronic card receives its transaction response.

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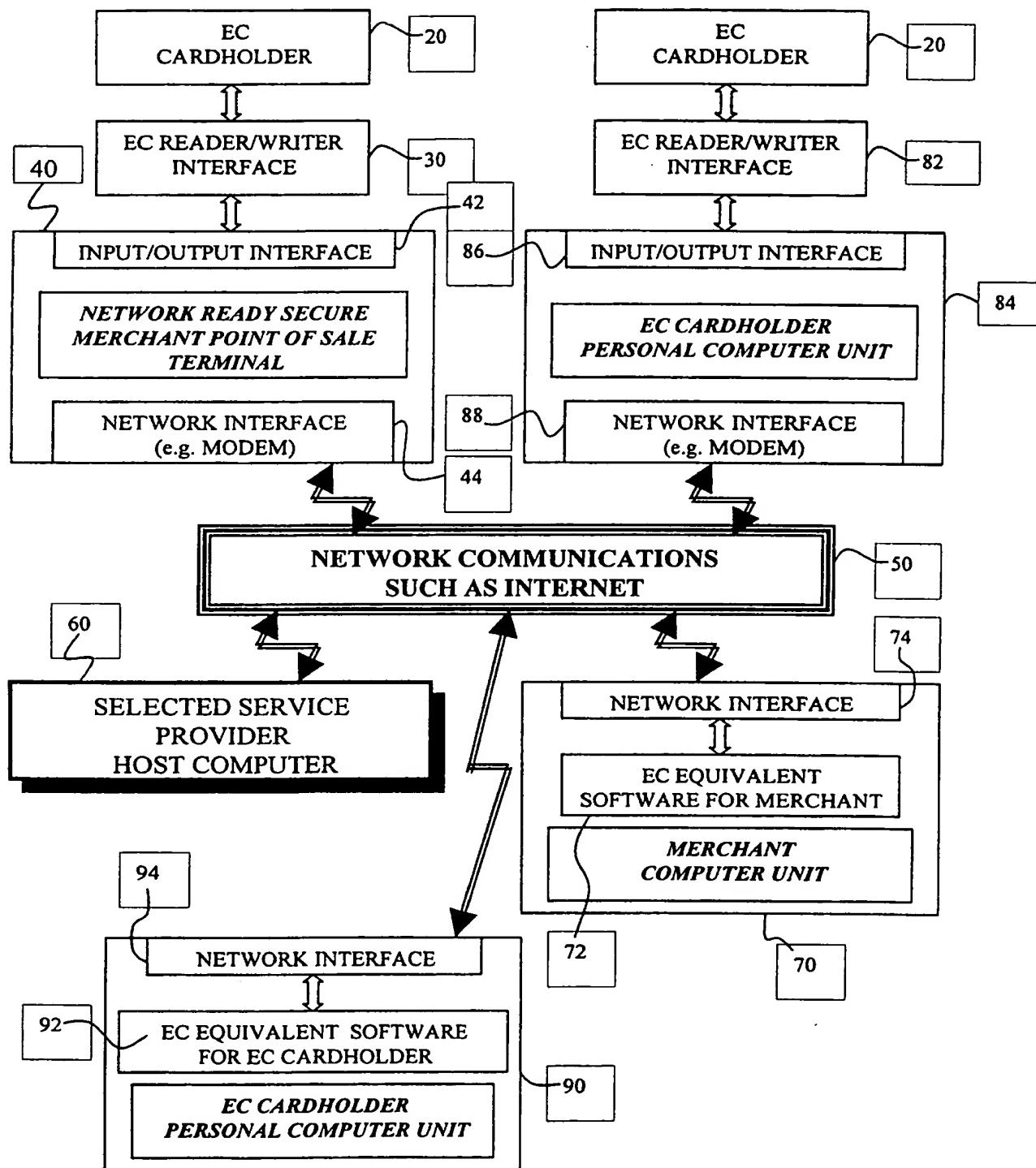
FIG. 1

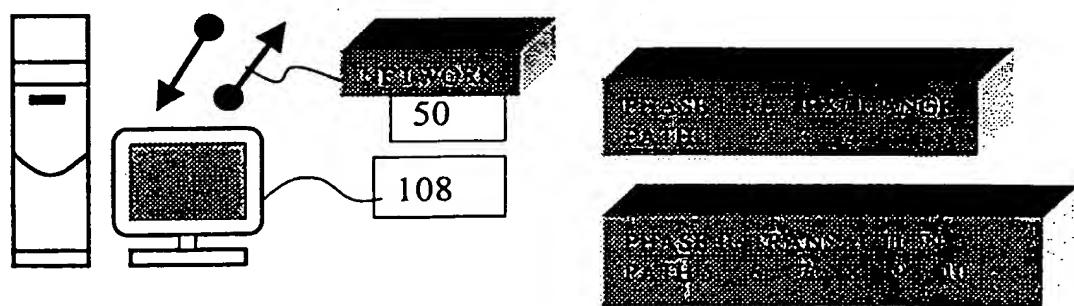
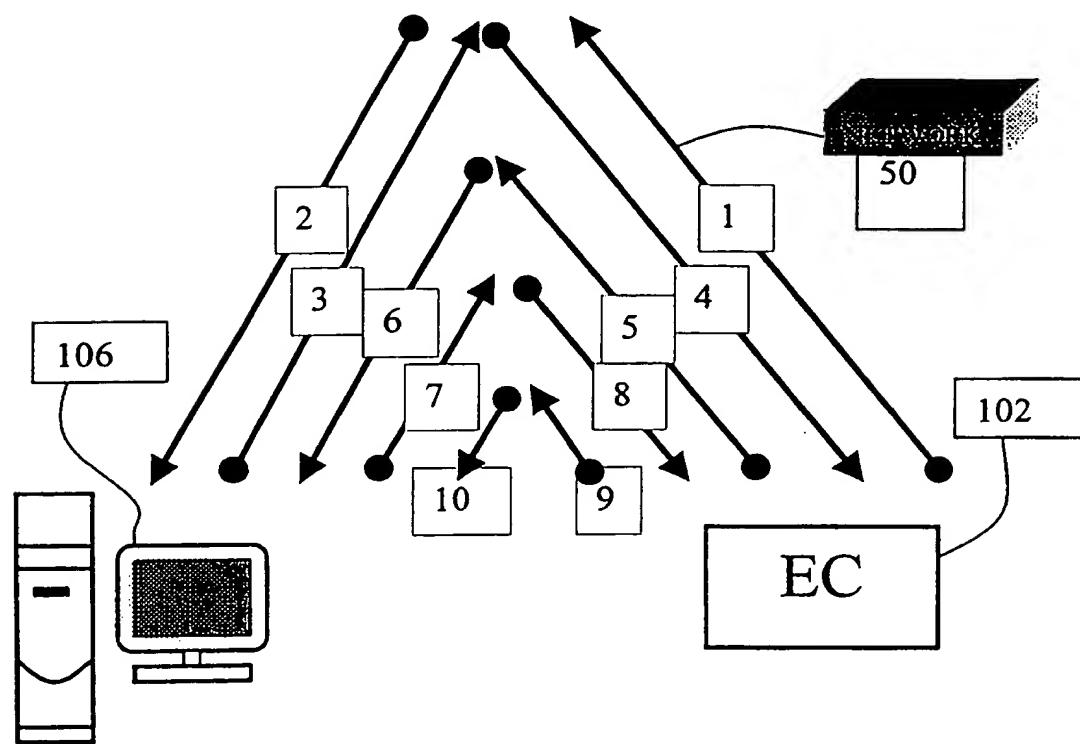
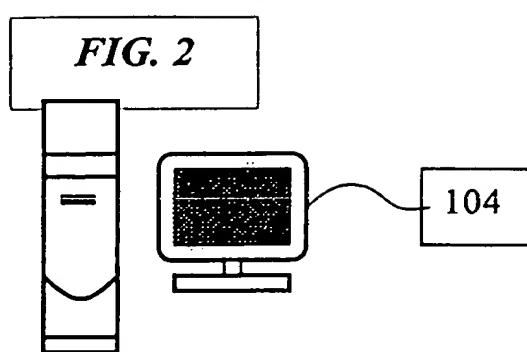
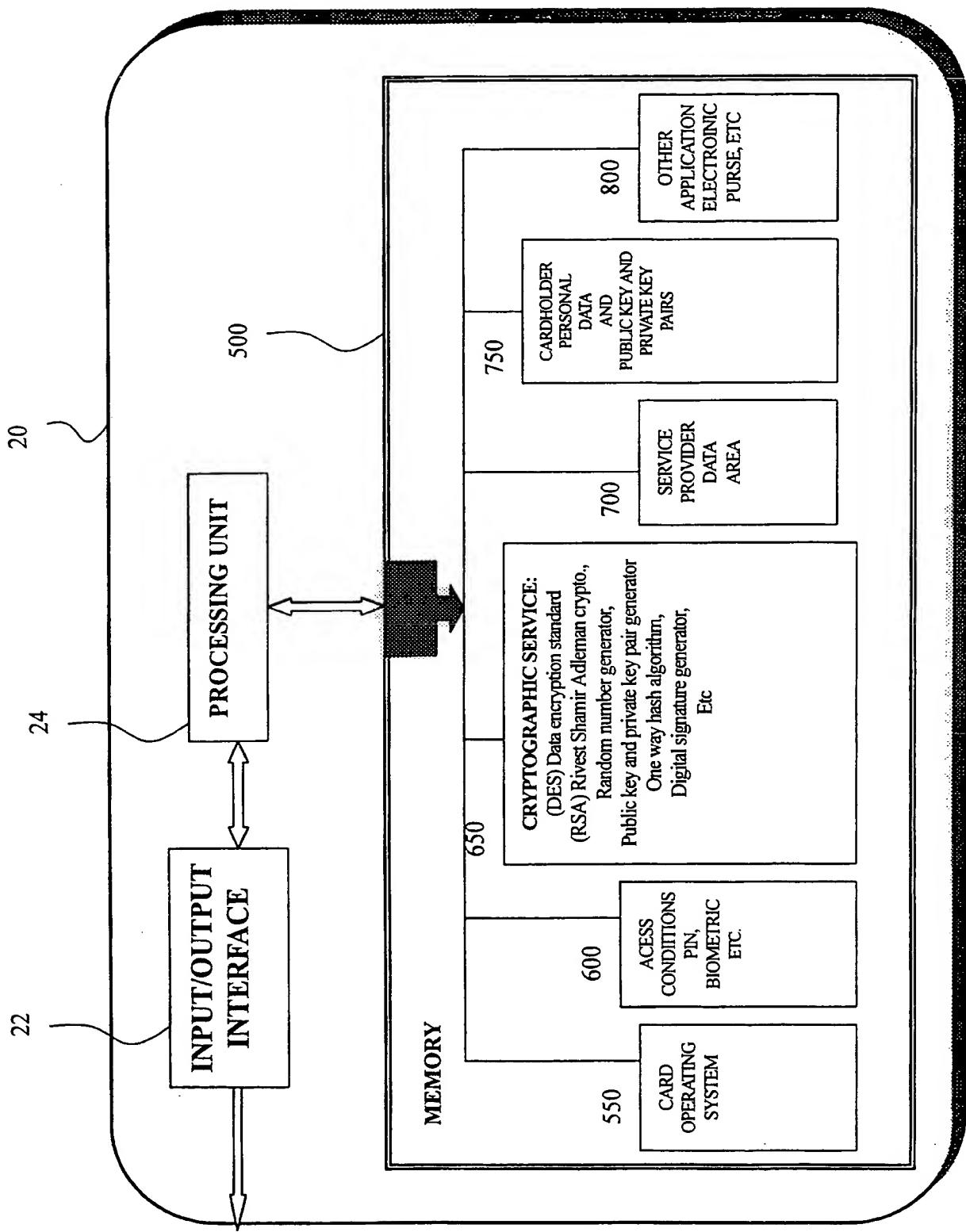
FIG. 2

FIG. 3



ELECTRONIC CARD

FIG. 4

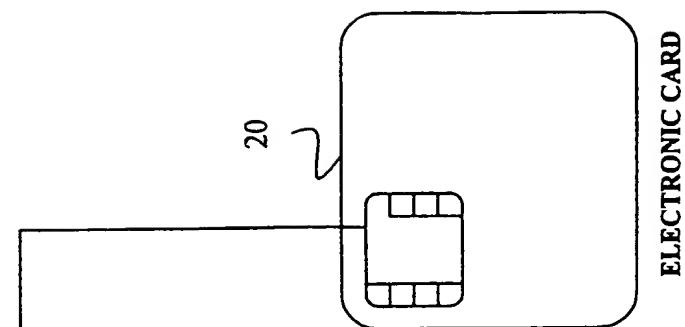


FIG. 5

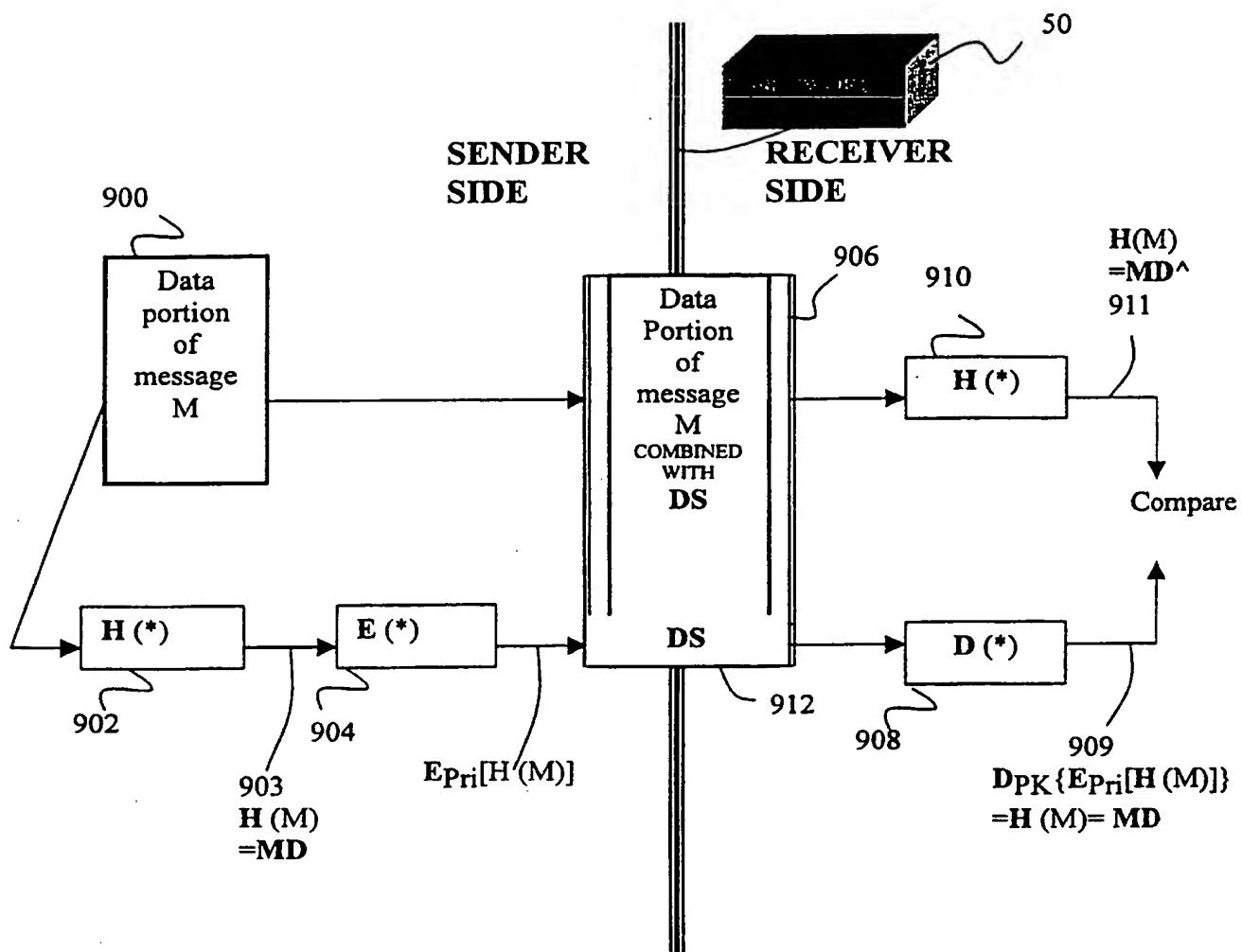


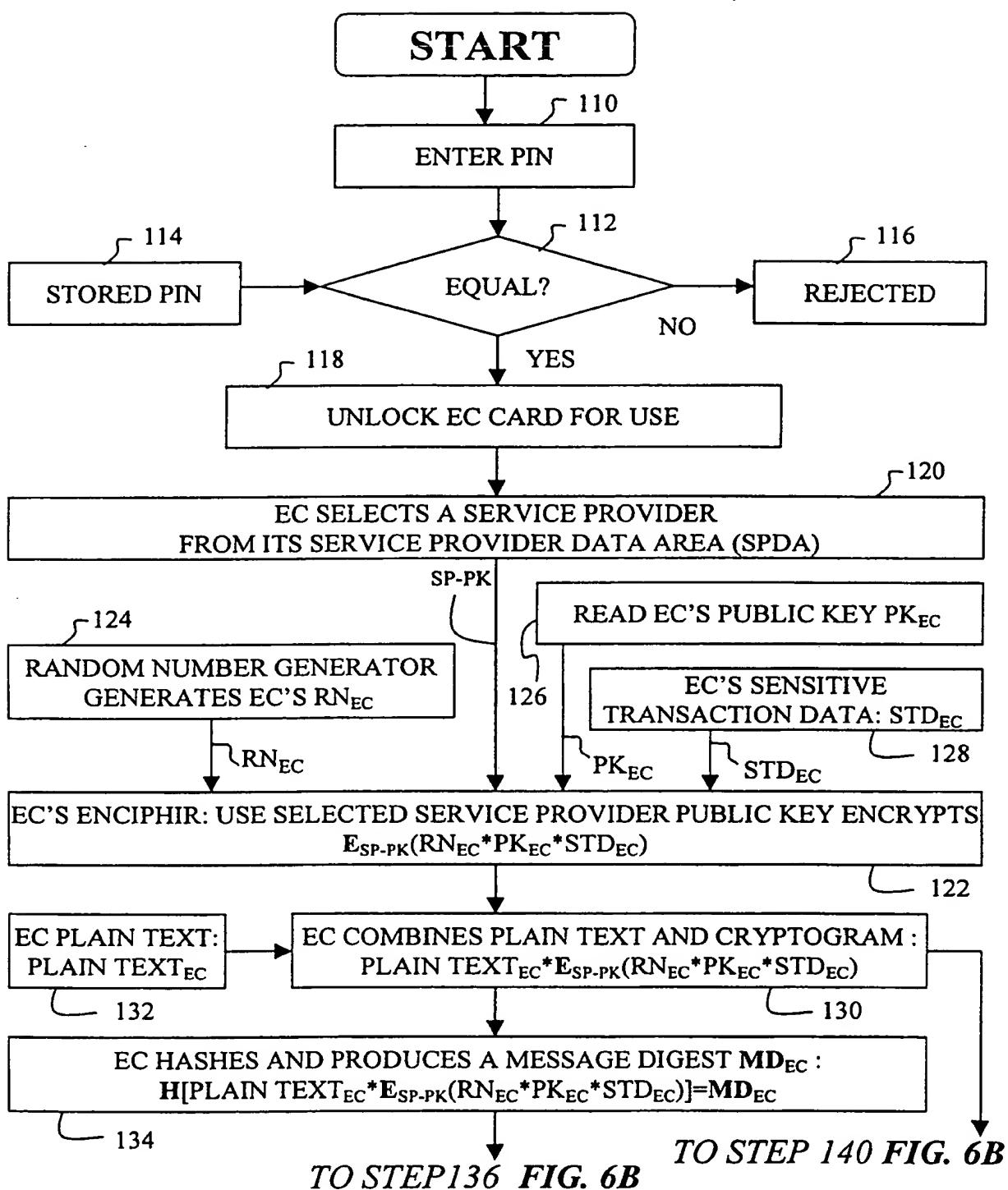
FIG. 6A

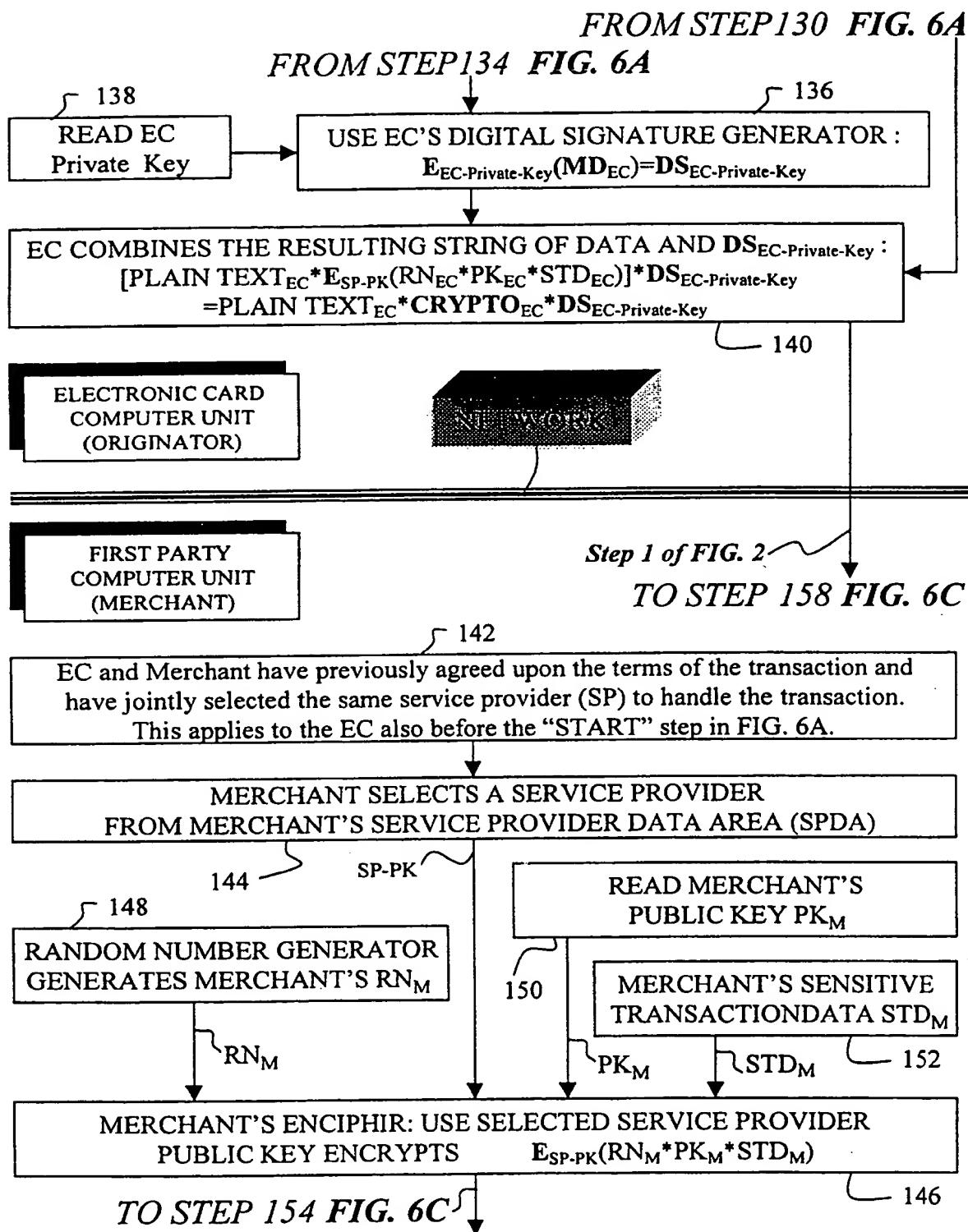
FIG. 6B

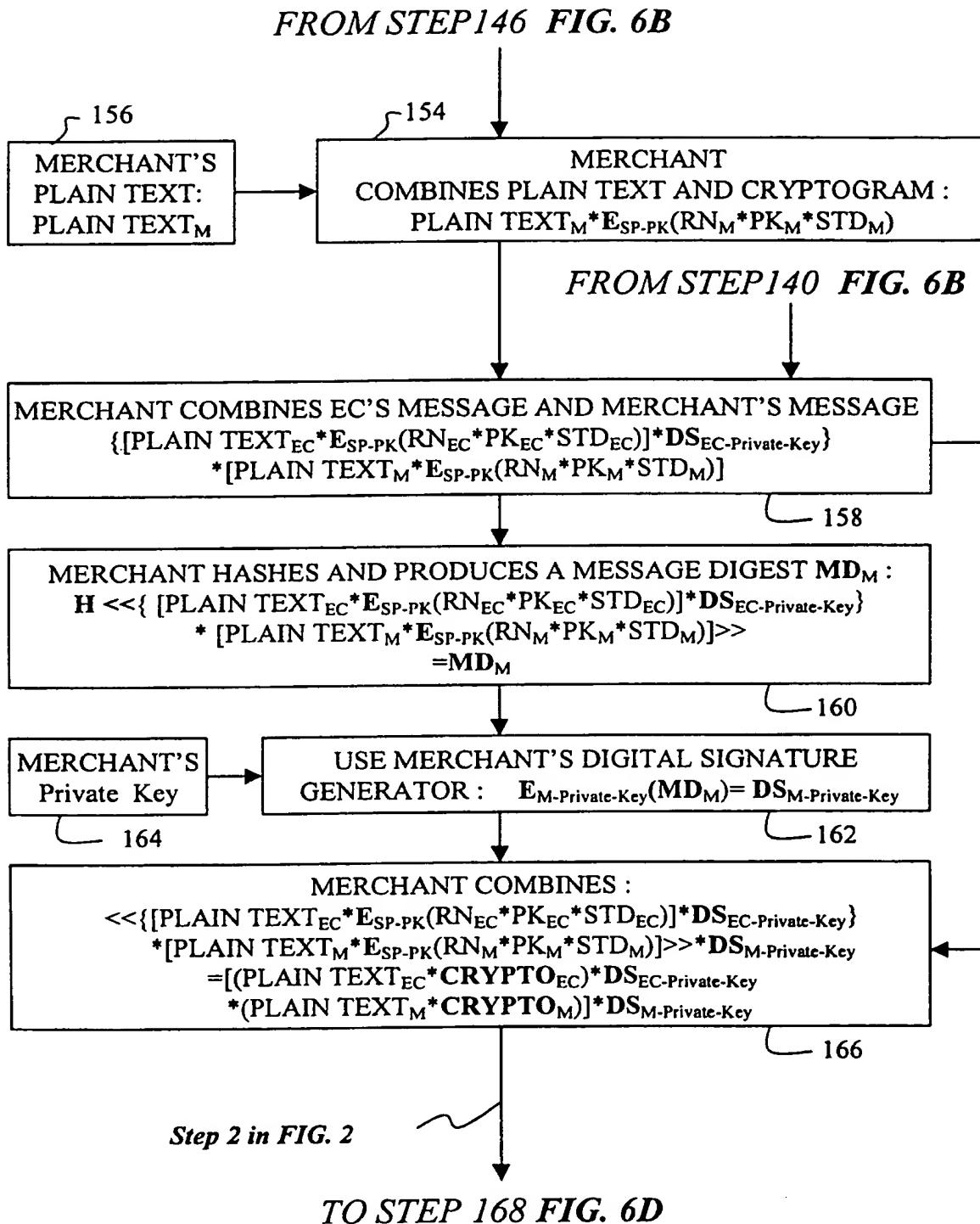
FIG. 6C

FIG. 6D**FROM STEP 166 FIG. 6C**

FIRST PARTY
COMPUTER UNIT
(MERCHANT)

SECOND PARTY
COMPUTER UNIT
(SERVICE PROVIDER)

NETWORKS

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SP separates the $DS_{M\text{-Private-Key}}$ from the data portion of the message and hashes the data portion of the message to obtain MD^M . SP separates the data portion of the message yielding components: $(PLAIN\ TEXT_{EC} * CRYPTO_{EC} * DS_{EC\text{-Private-Key}})$, $PLAIN\ TEXT_M$, $CRYPTO_M$, $DS_{M\text{-Private-Key}}$

SP uses $SP_{Private\text{-Key}}$ to decrypt $CRYPTO_M$ to obtain PK_M , and is used to verify the $DS_{M\text{-Private-Key}}$.

REJECT

NO

 $MD^M = MD_M ?$

YES

170

172

176

- (1) SP separates $DS_{EC\text{-Private-Key}}$, hashes: $H(PLAIN\ TEXT_{EC} * CRYPTO_{EC}) = MD^E$
- (2) Separates EC's KE request message and becomes: $PLAIN\ TEXT_{EC}$, $CRYPTO_{EC}$, $DS_{EC\text{-Private Key}}$
- (3) SP uses $SP_{Private\text{-Key}}$ to decrypt $CRYPTO_{EC}$ to obtain PK_{EC} , RN_{EC} , and uses PK_{EC} to verify the $DS_{EC\text{-Private-Key}}$

REJECT

NO

 $MD^E = MD_E ?$

YES

178

RANDOM NUMBER
GENERATOR SP GENERATES
RN TO EC: $RN_{SP\text{-EC}}$

184

TO STEP 206 FIG. 6F

SP GENERATES ONE SESSION
KEY FOR EC : $Skey_{EC}$

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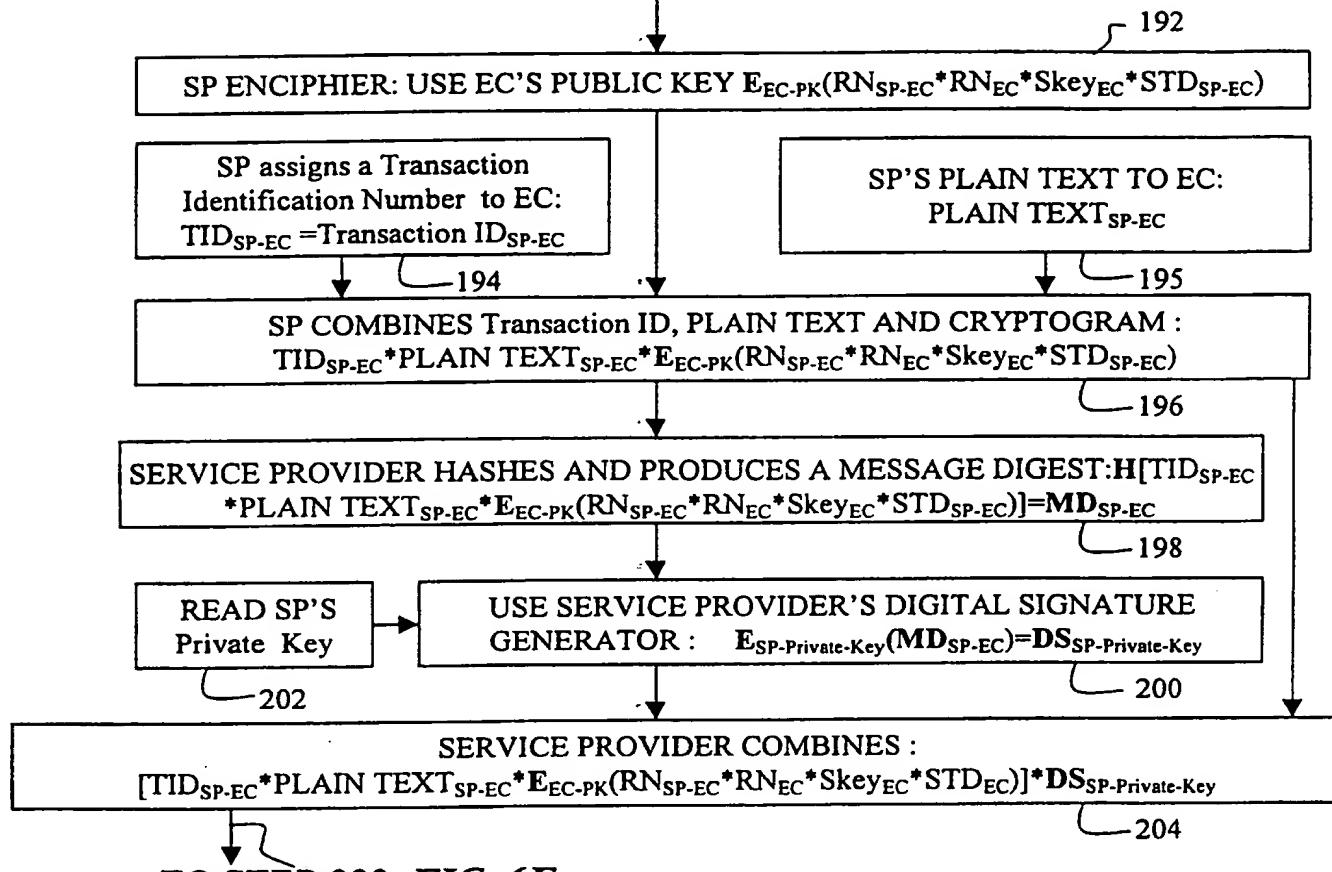
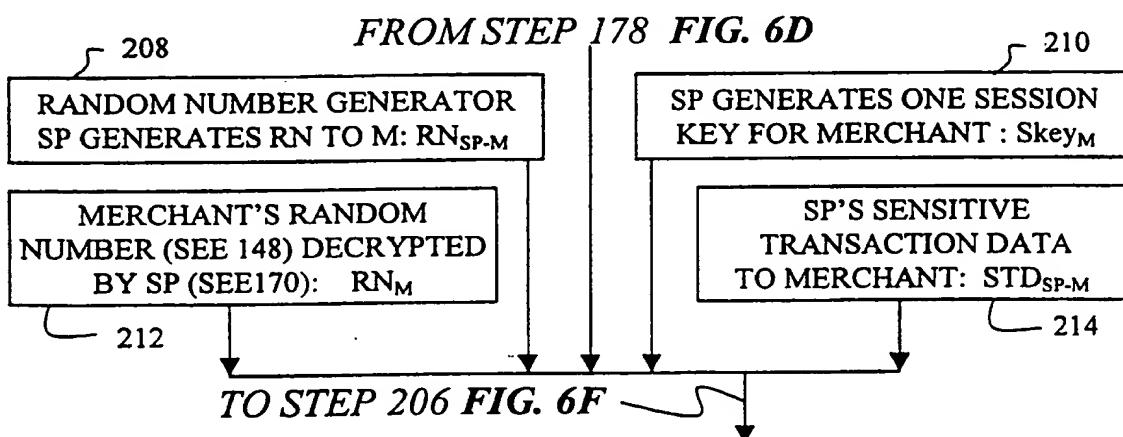
EC'S RANDOM NUMBER
(SEE 124) DECRYPTED BY
SP (SEE 176): RN_{EC}

188

SP'S SENSITIVE TRANSACTION
DATA TO EC: $STD_{SP\text{-EC}}$

190

TO STEP 182 FIG. 6E

FIG. 6E**FROM STEPS 184, 186, 188, 190 FIG. 6D****FROM STEP 178 FIG. 6D**

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FIG. 6F

FROM STEPS 208, 210, 212, 214 FIG 6E

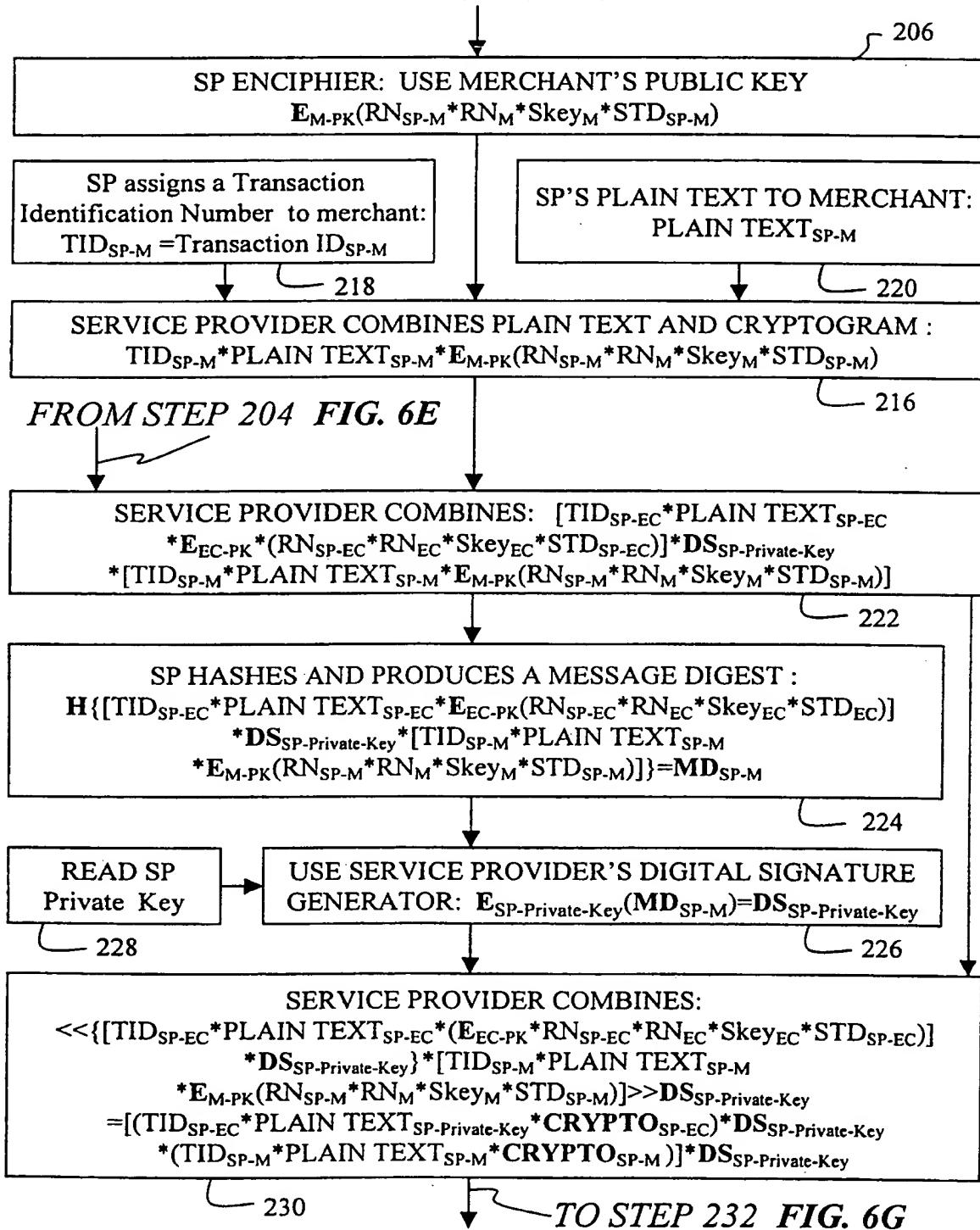


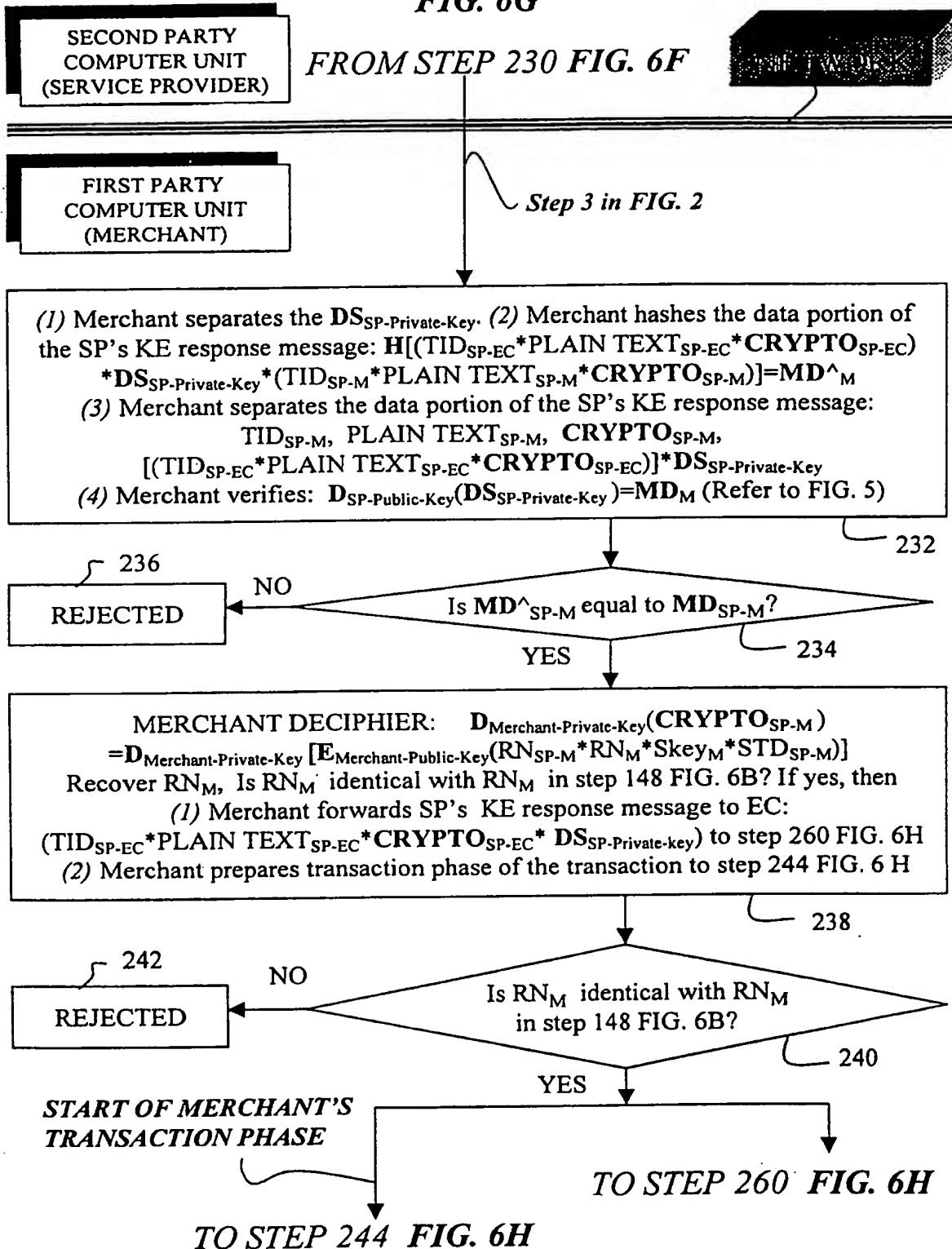
FIG. 6G

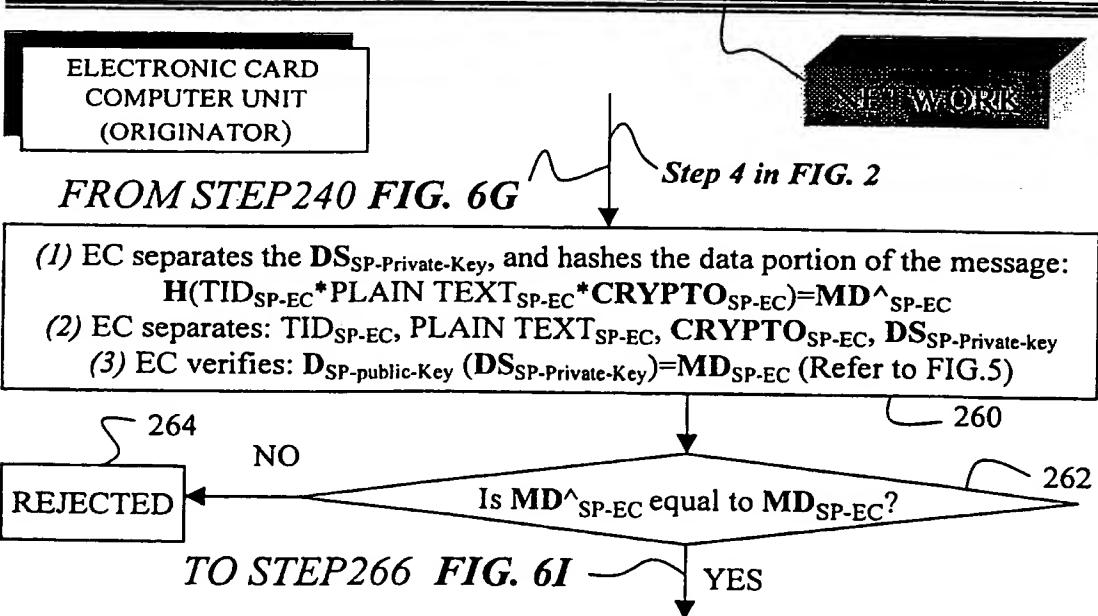
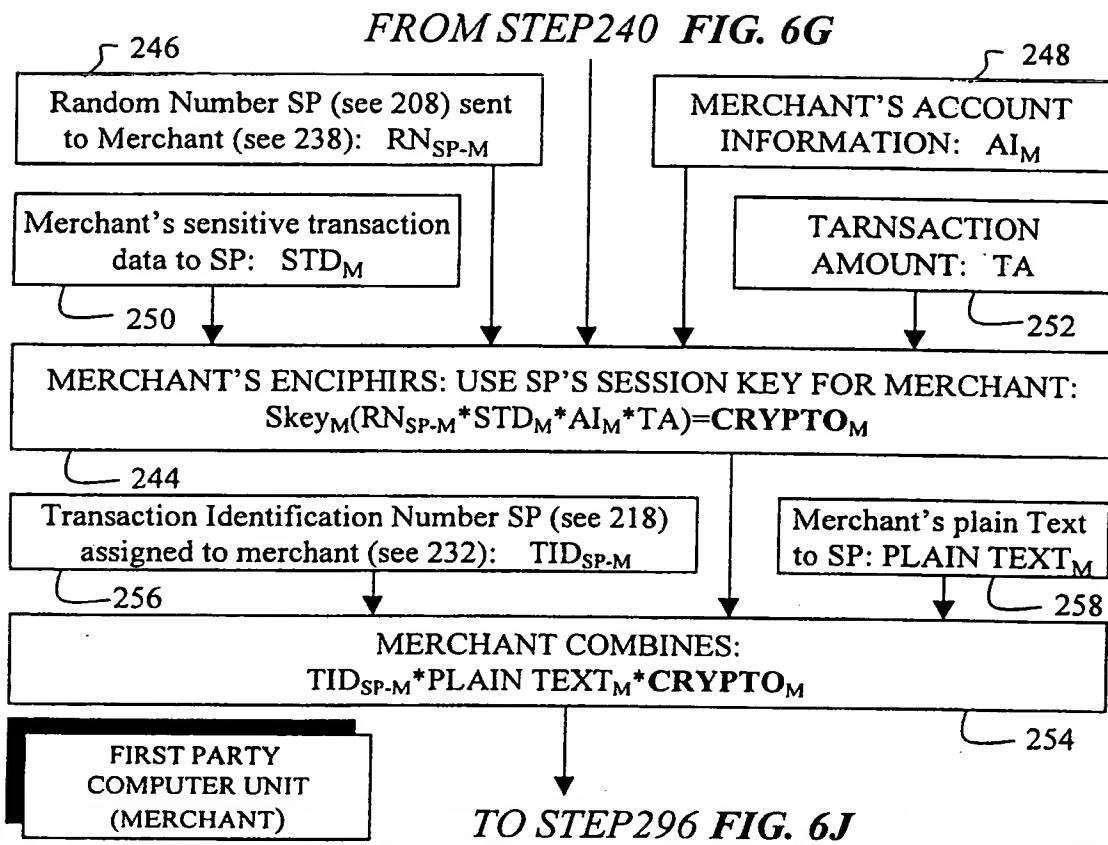
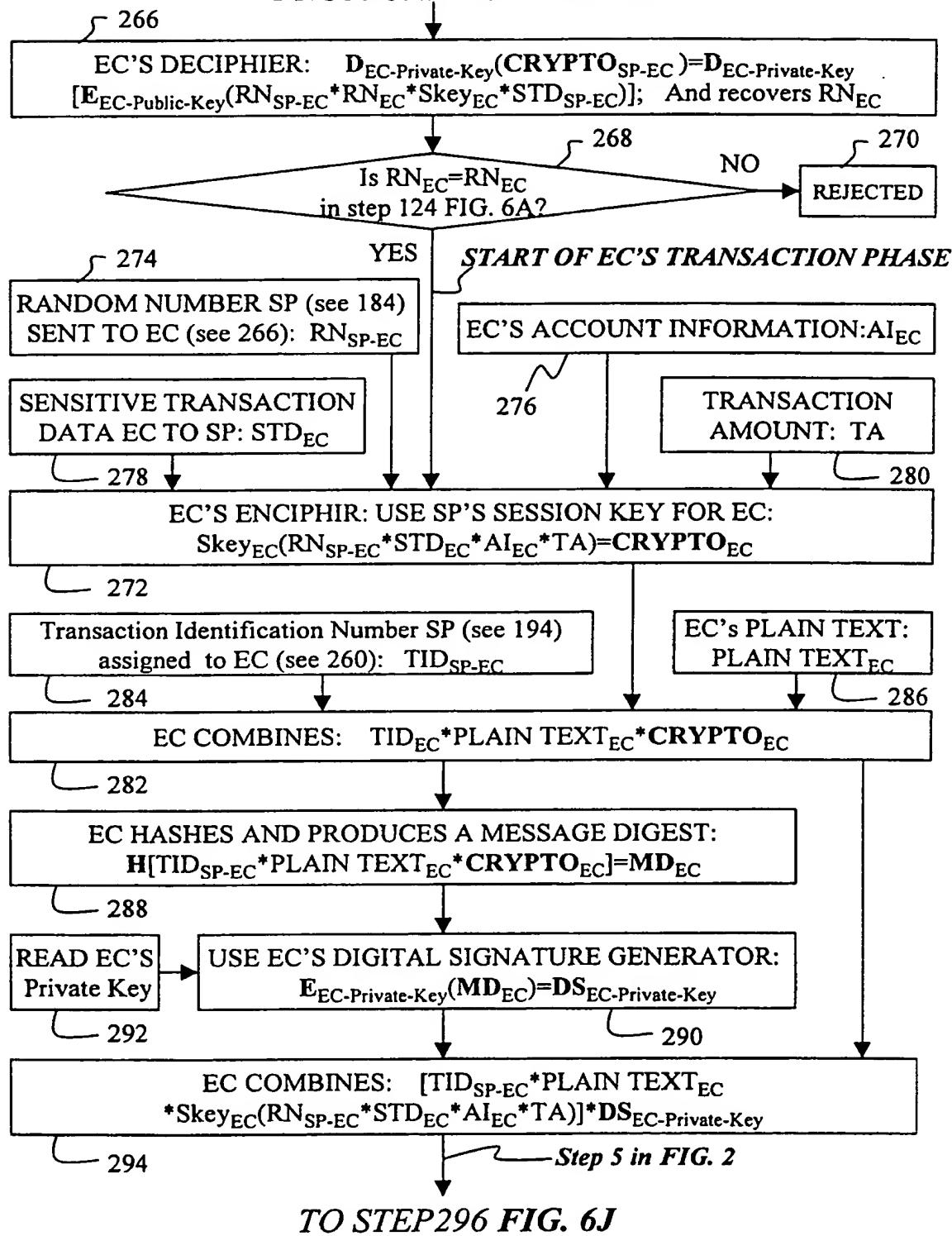
FIG. 6H

FIG. 6I
FROM STEP 262 FIG. 6H



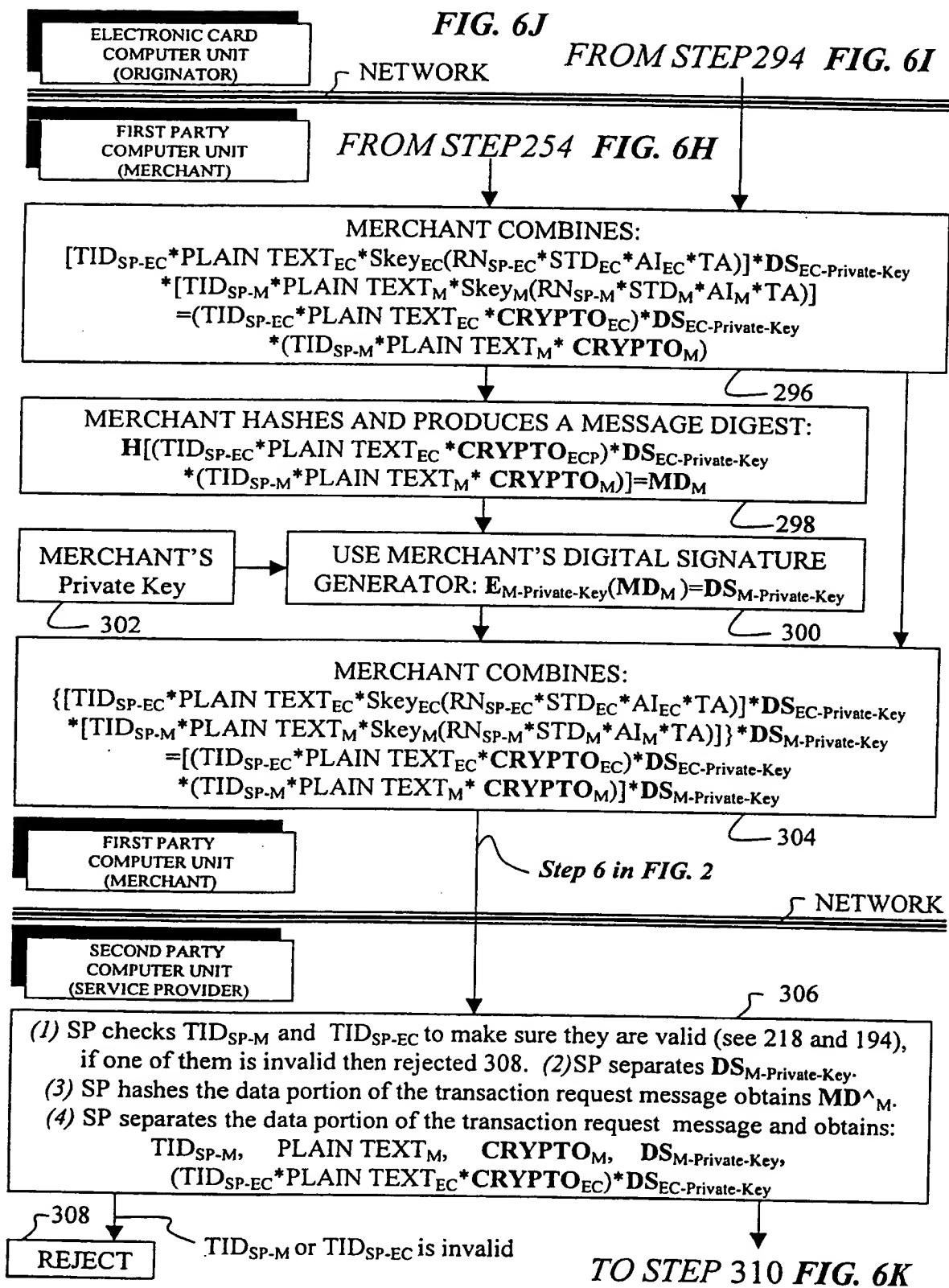


FIG. 6K
FROM STEP 306 FIG. 6J

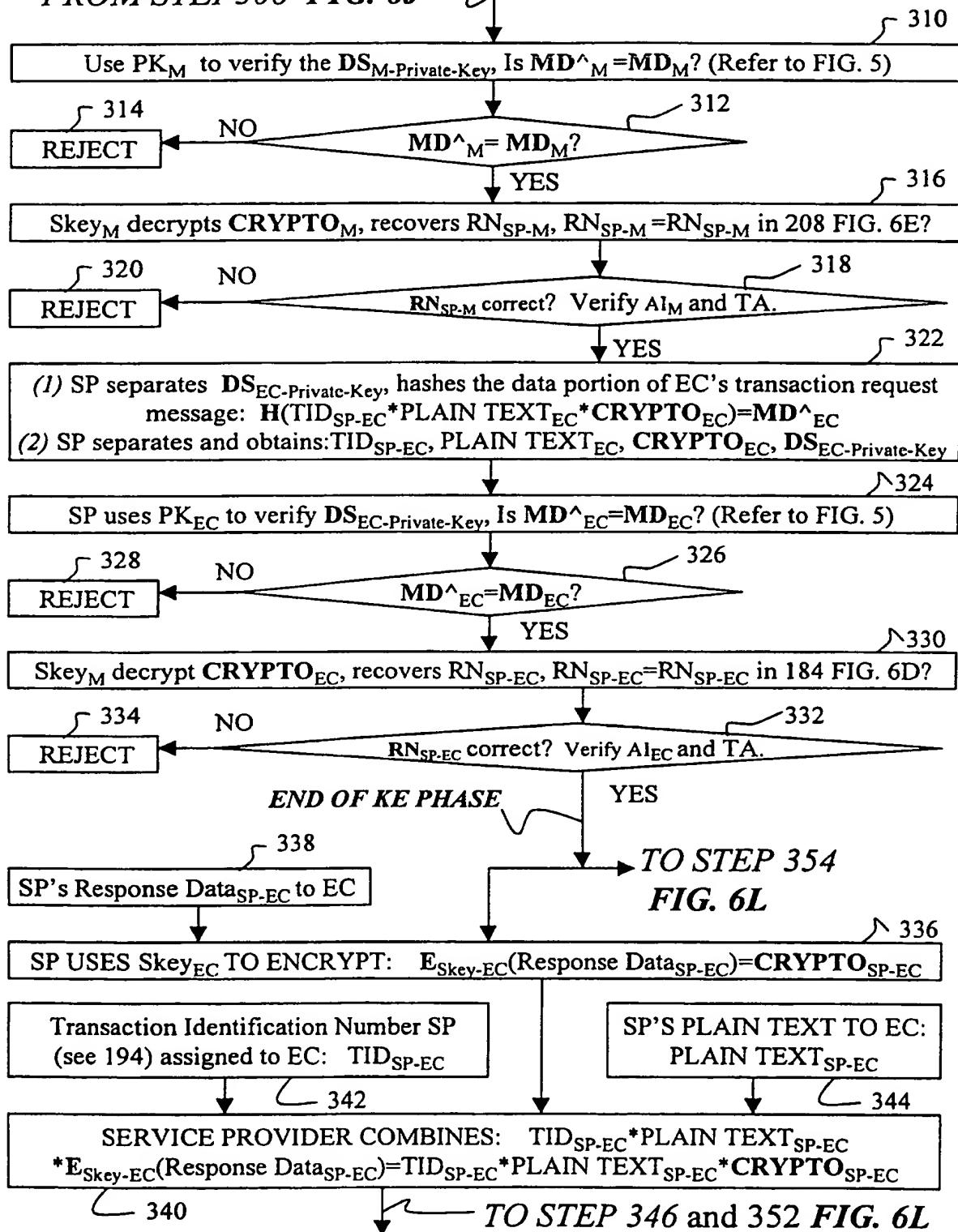


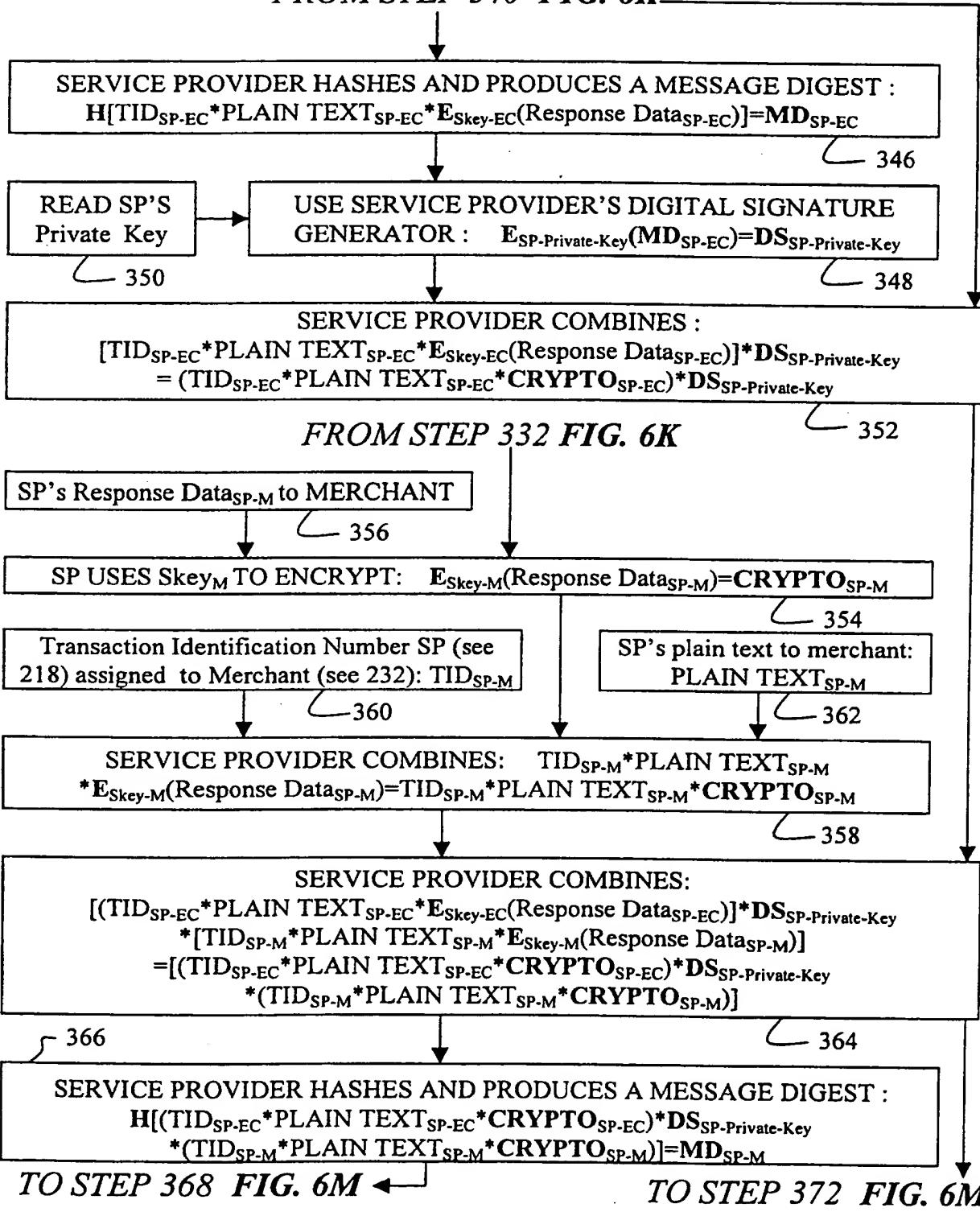
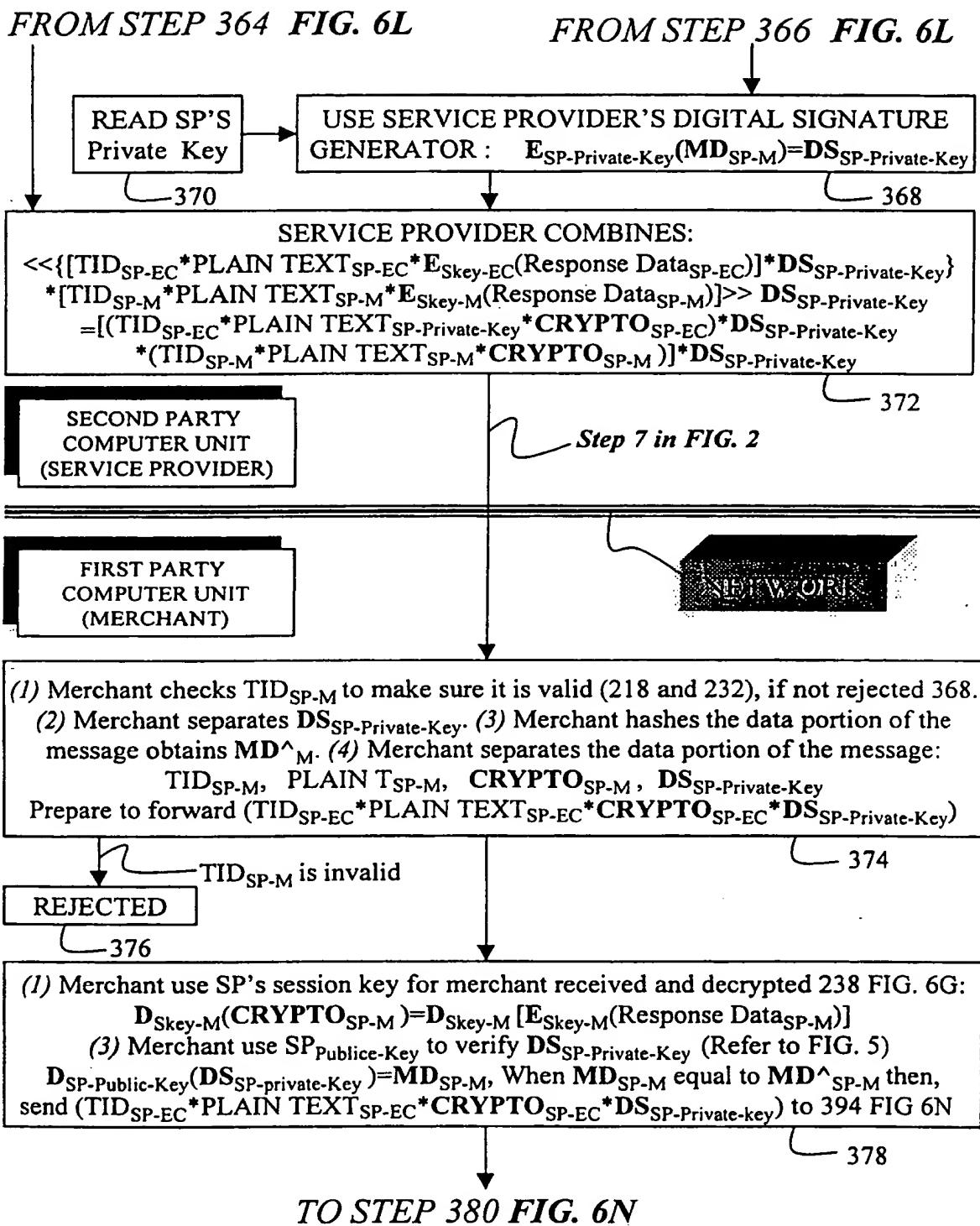
FIG. 6L**FROM STEP 340 FIG. 6K**

FIG. 6M

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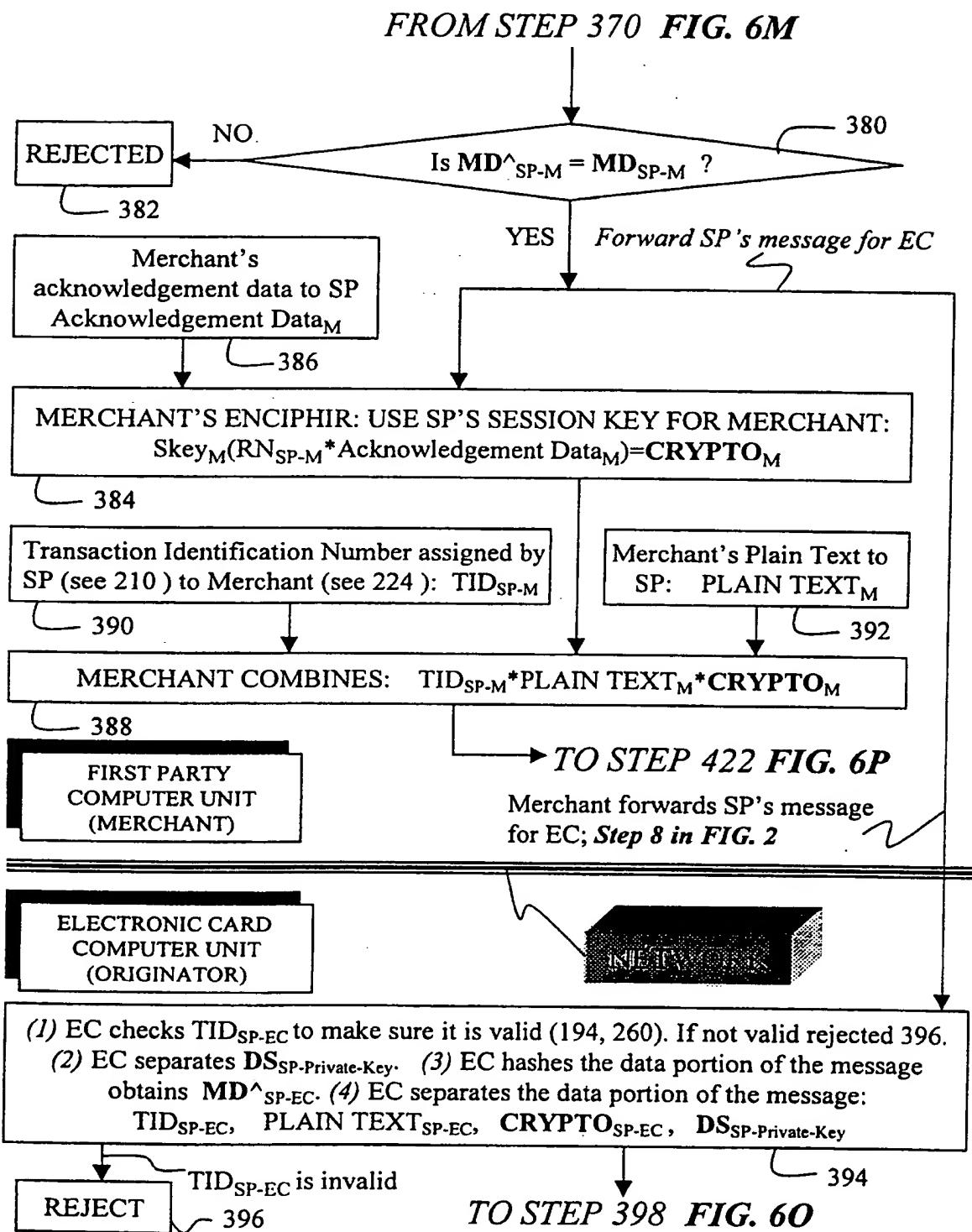
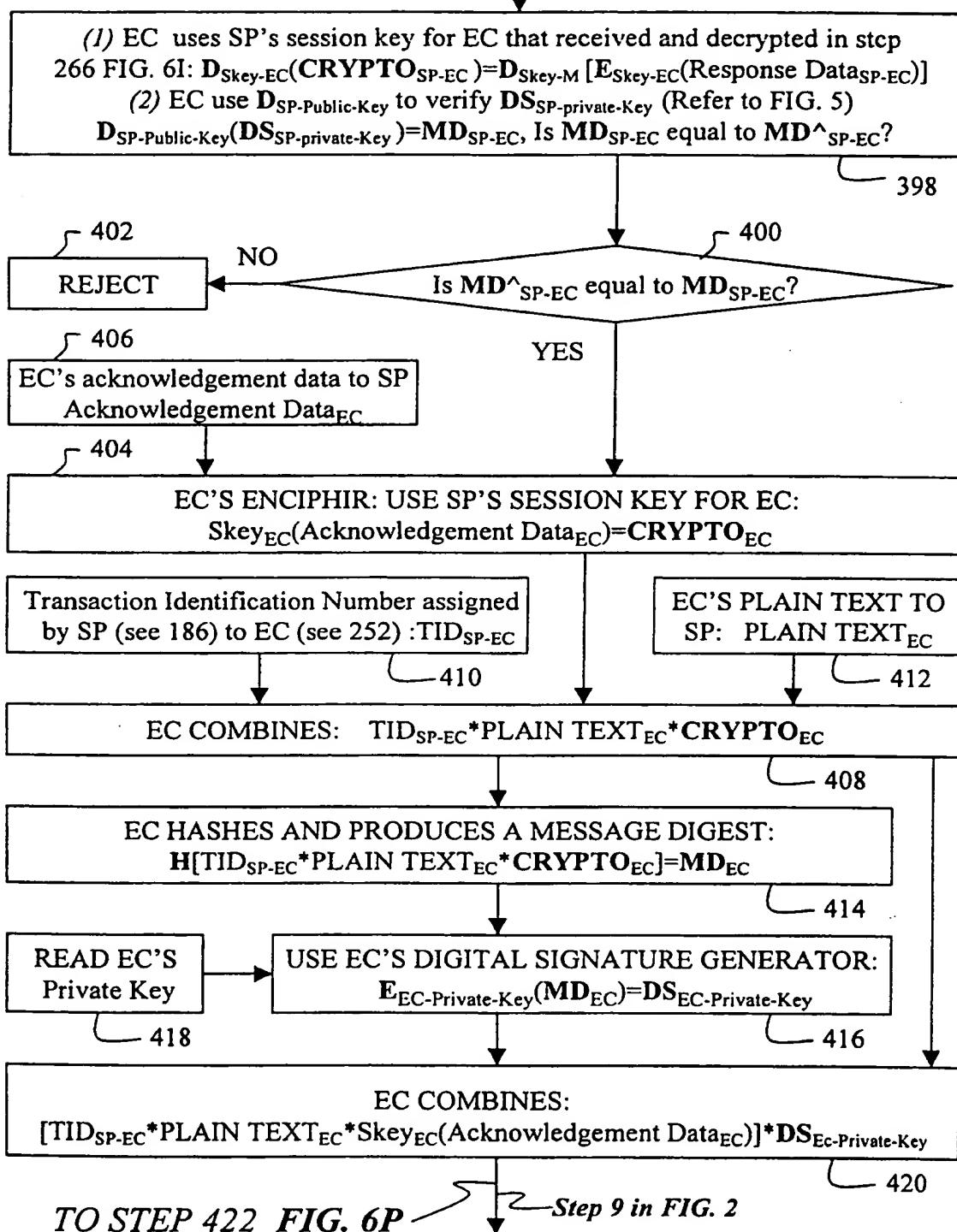
FIG. 6N

FIG. 6O

FROM 394 FIG. 6N



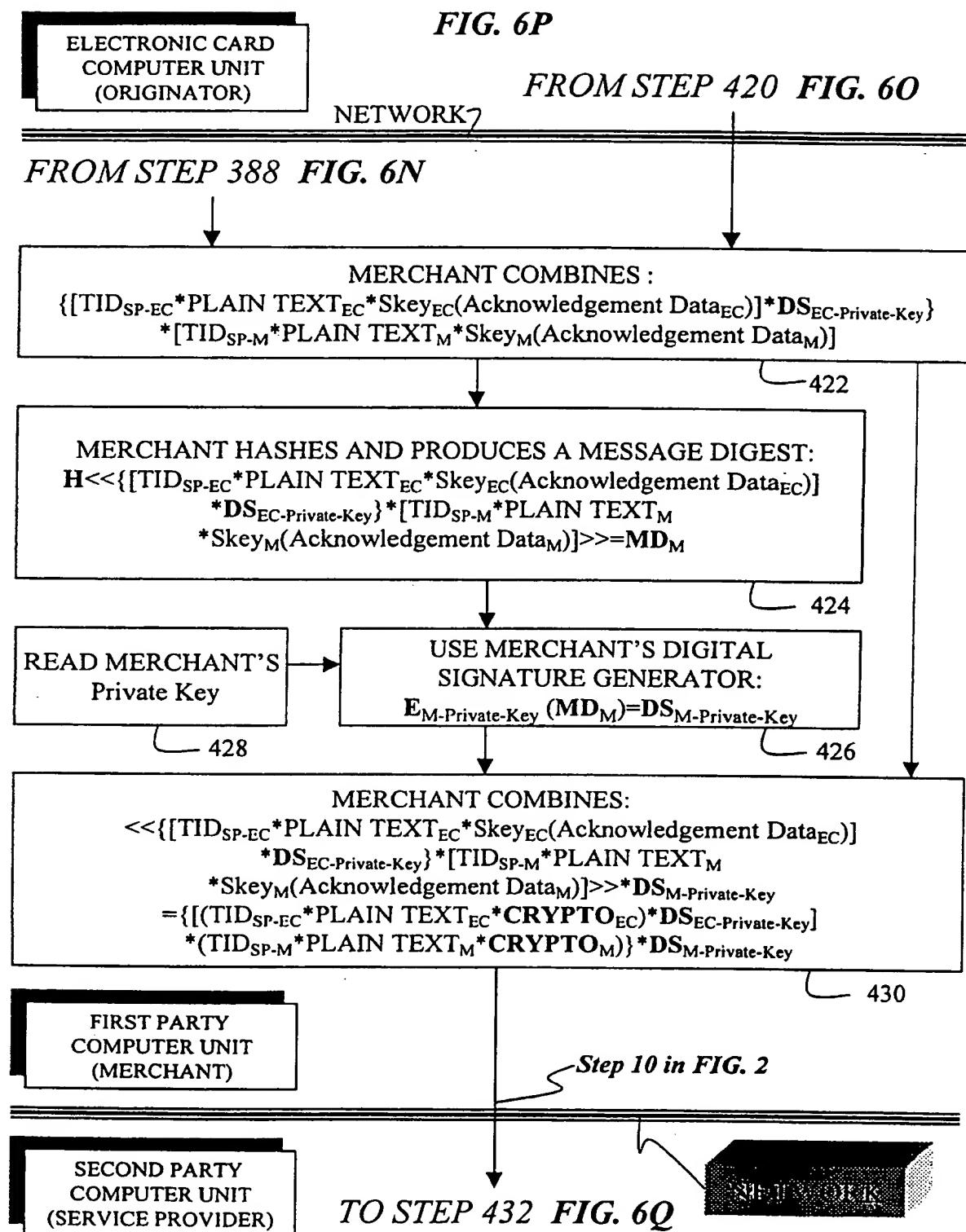


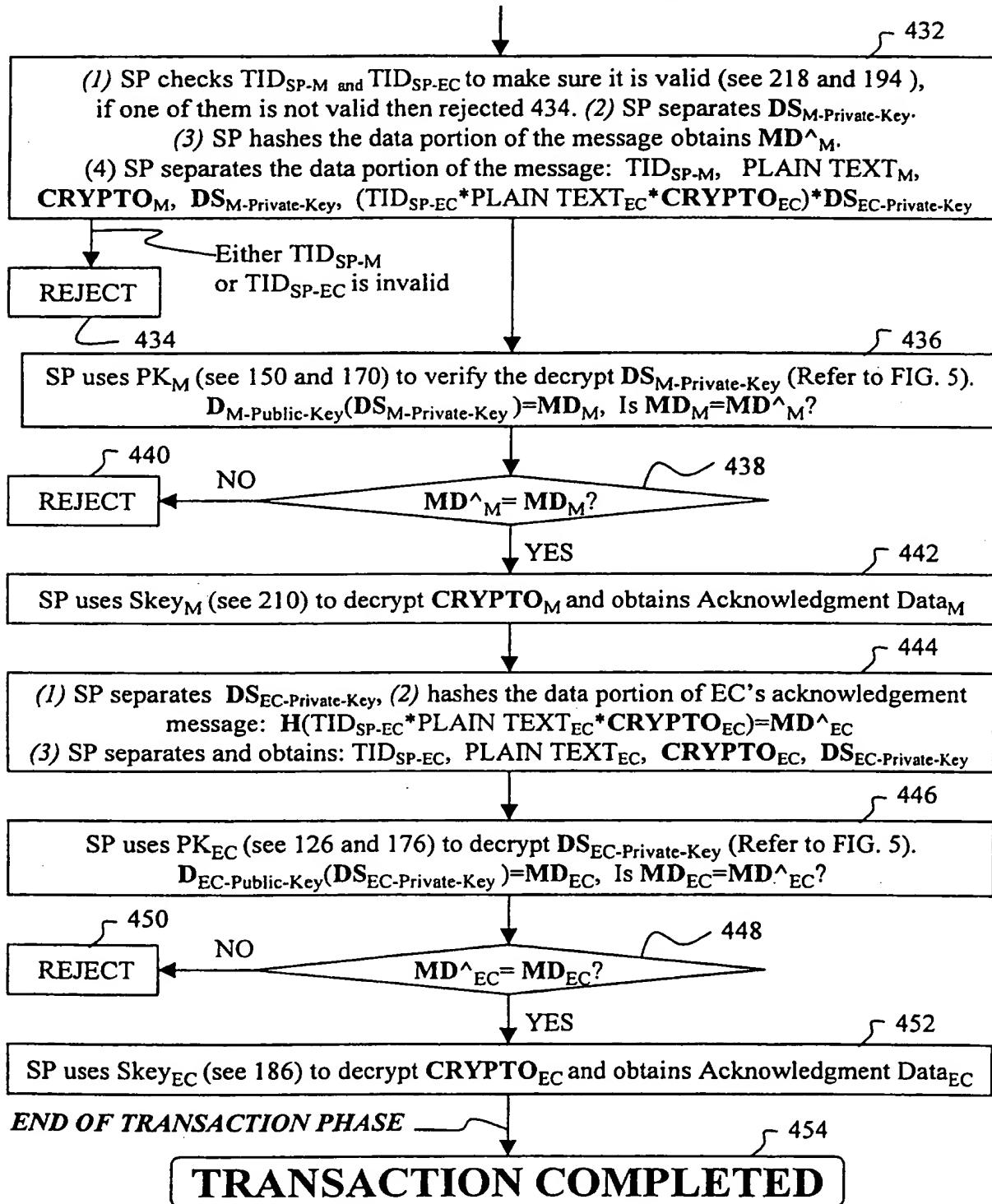
FIG. 6Q**FROM STEP 430 FIG. 6P**

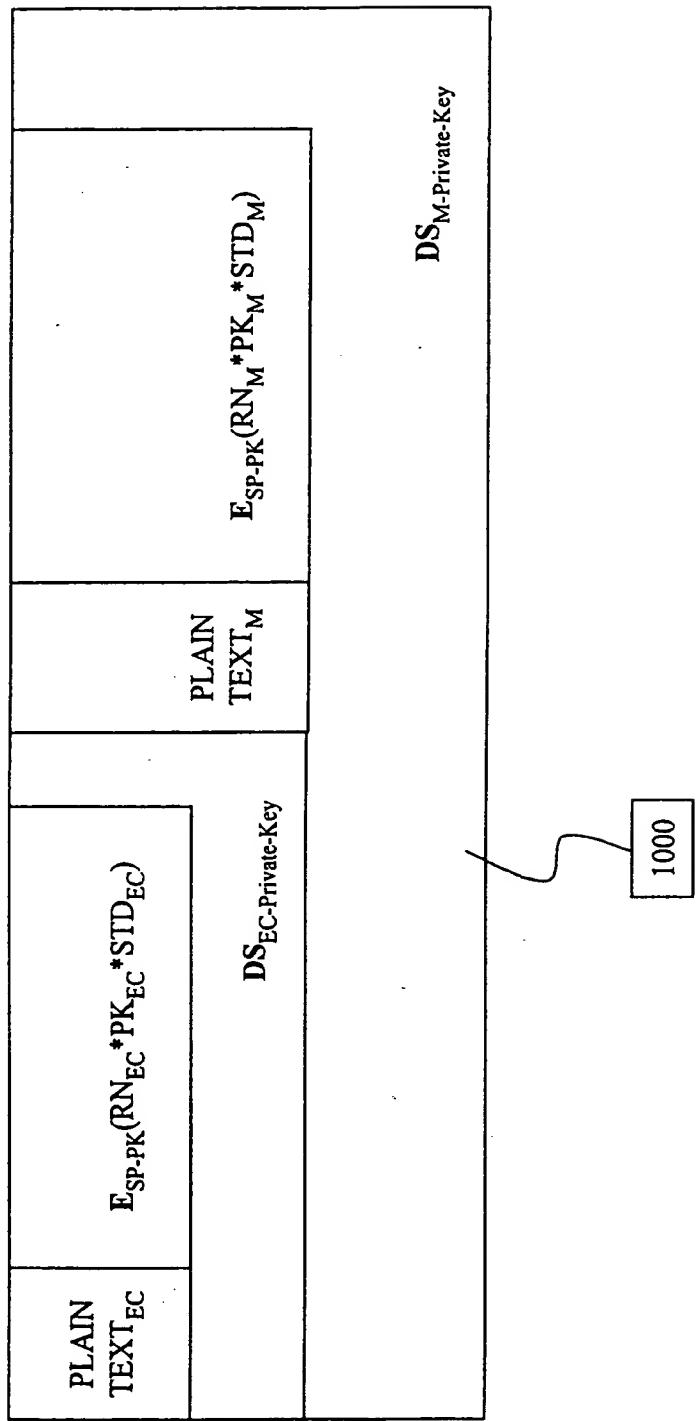
FIG. 7

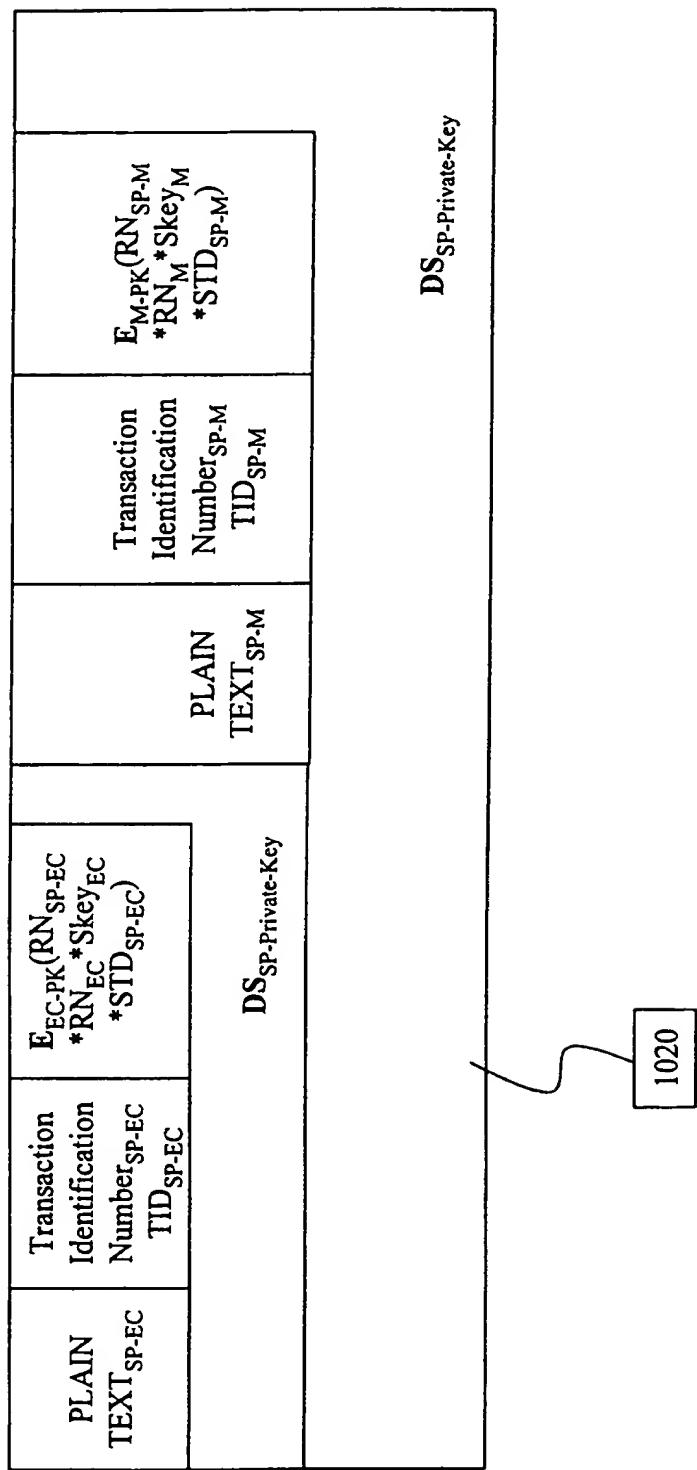
FIG.8

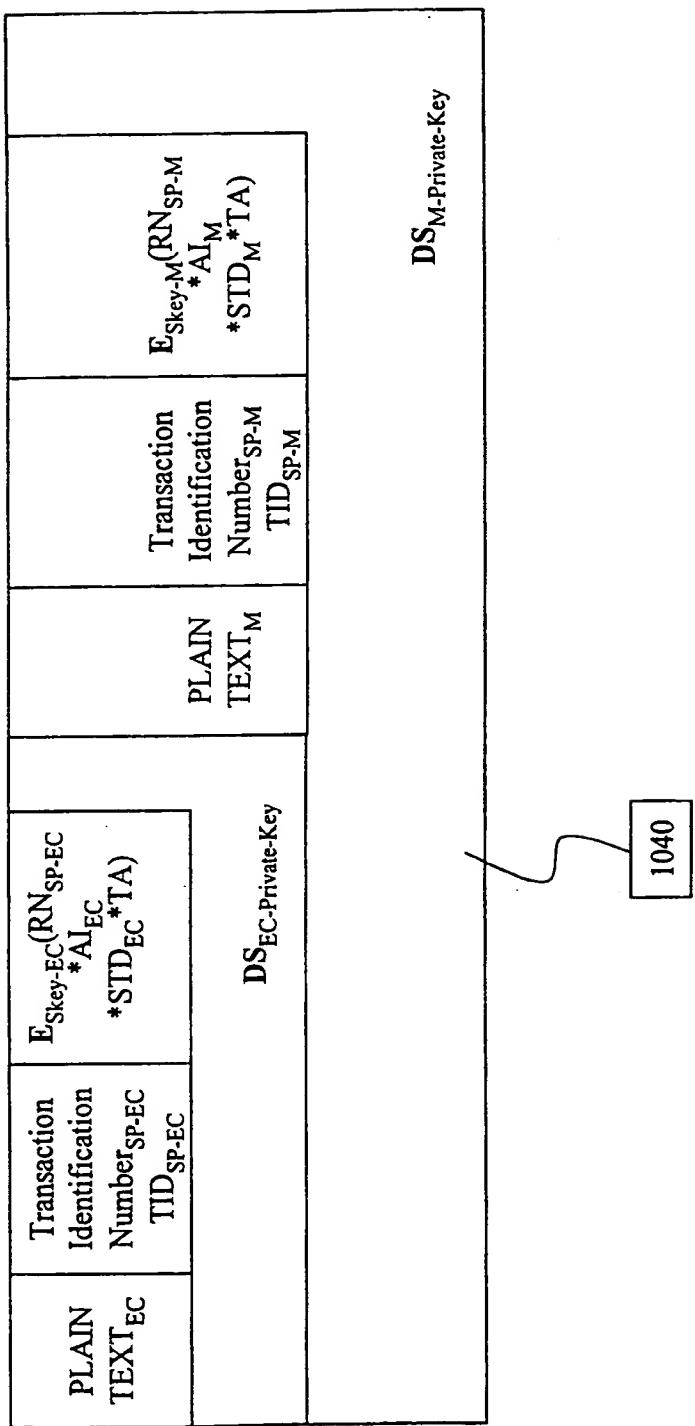
FIG.9

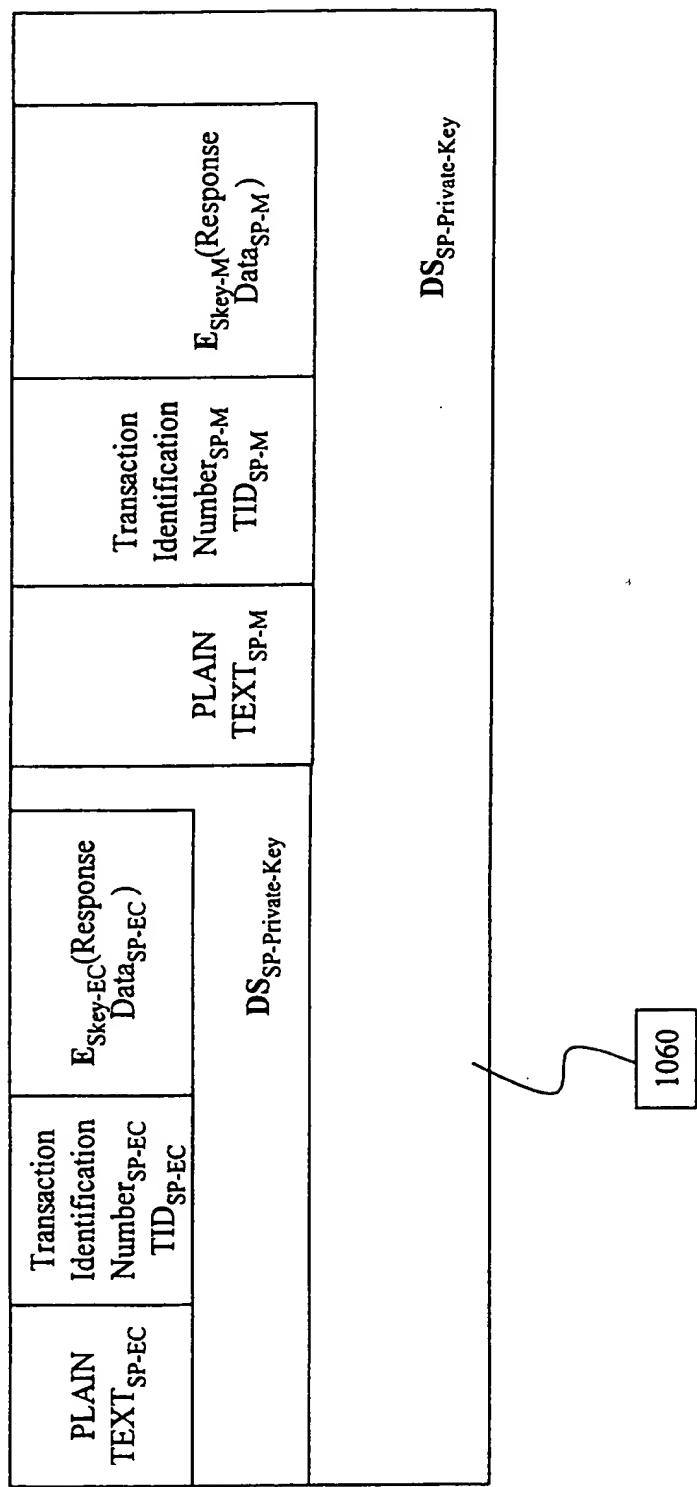
FIG.10

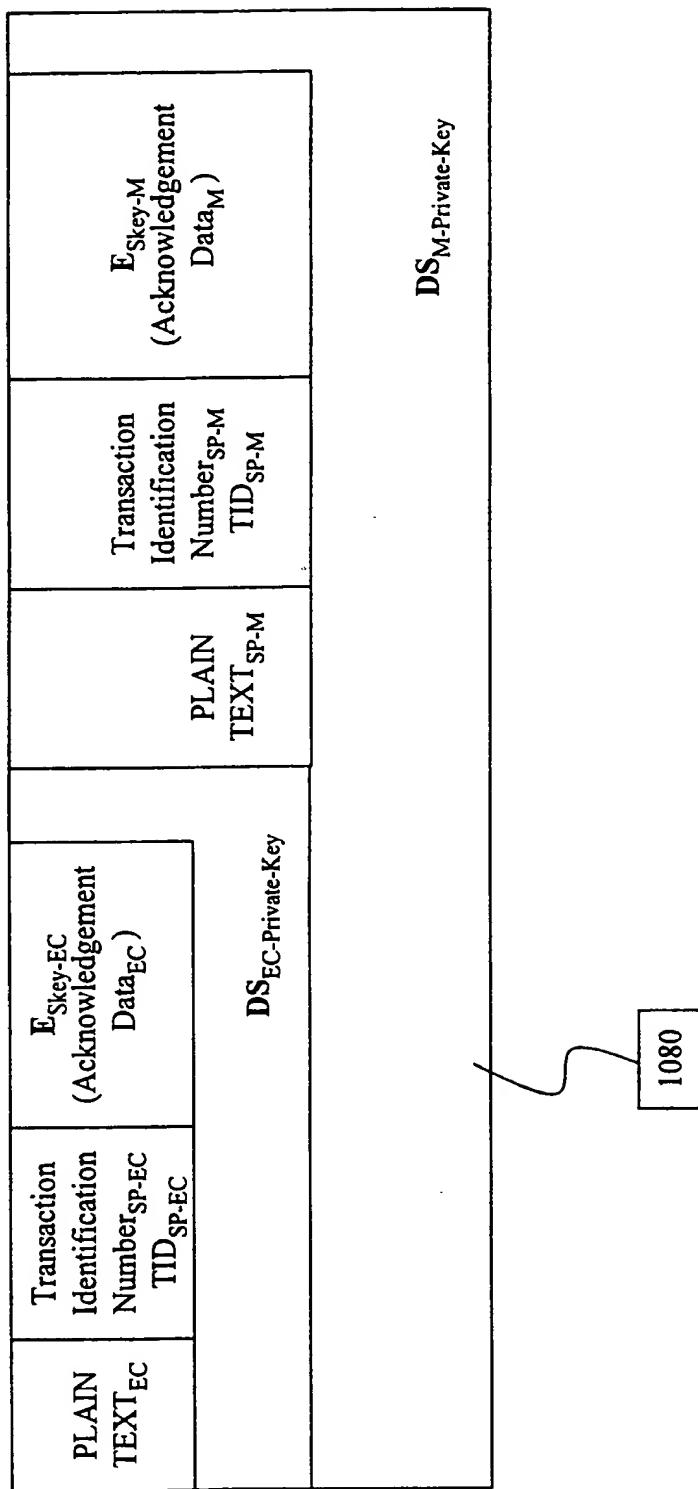
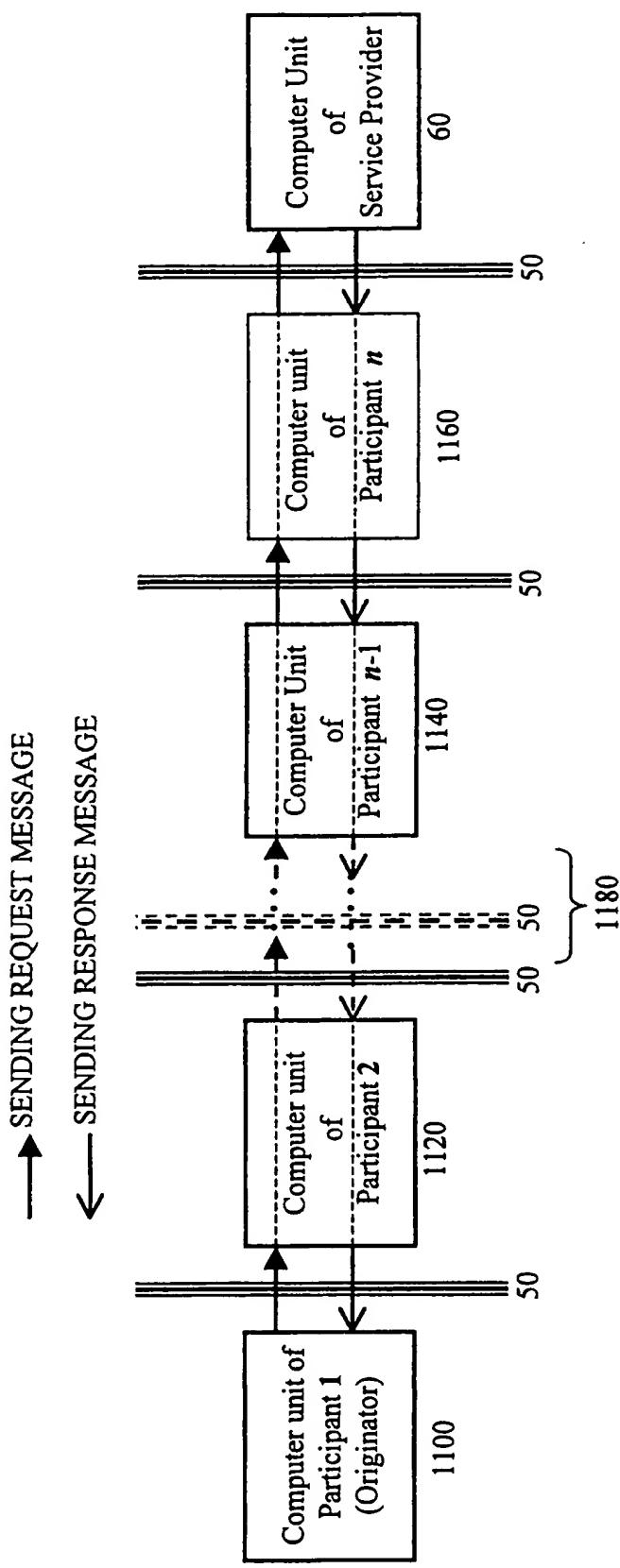
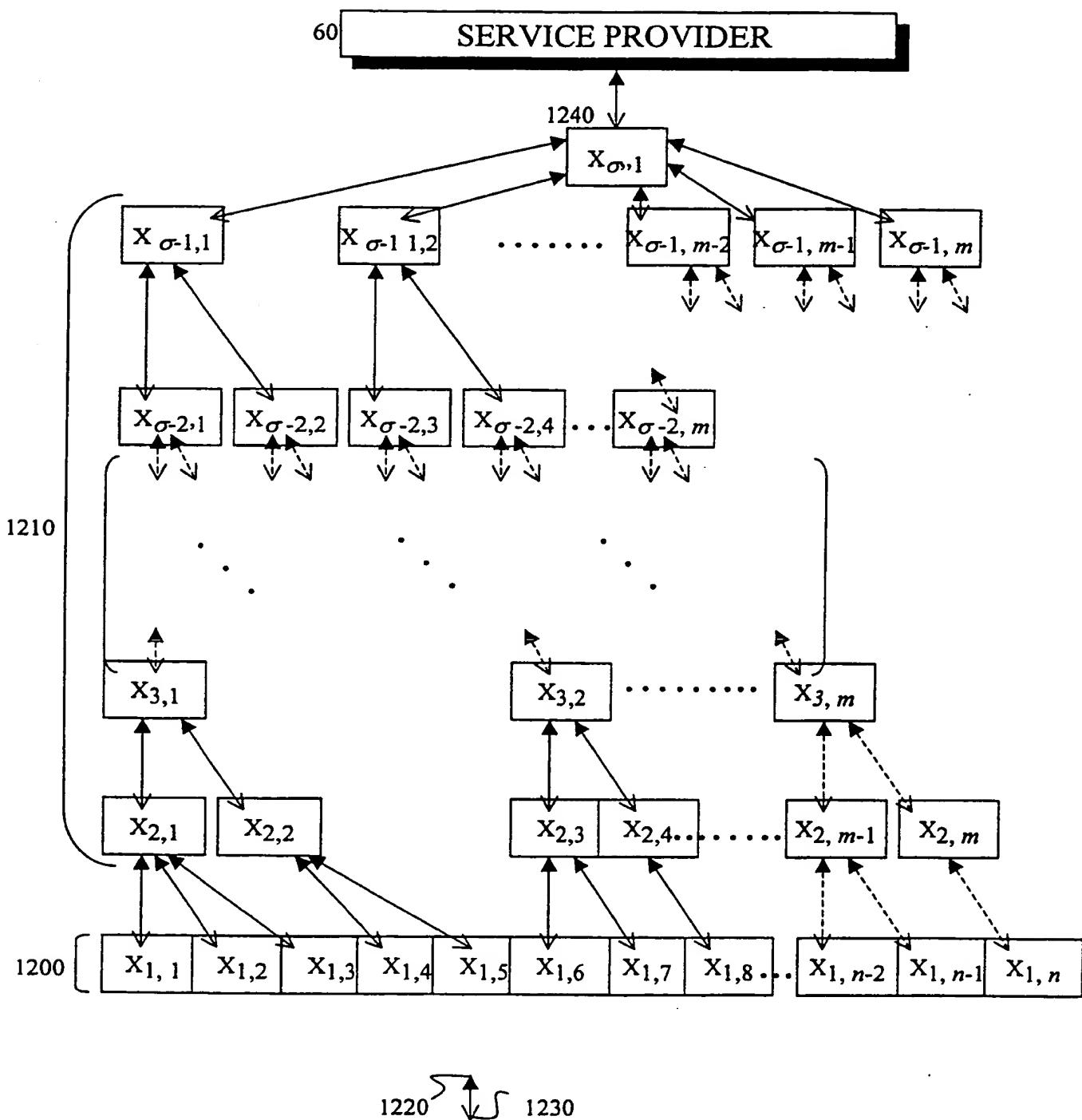
FIG.11

FIG. 12

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FIG. 13

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US99/09938

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) H 04 K 1/00; H 04 L 9/00

US CL 380/30, 49

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. 380/30, 49

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,544,246 A (MANDELBAUM et al) 06 August 1996, Figures 2-7, col. 2, lines 9-33.	1-11
Y	SCHNEIER, BRUCE. Applied Cryptography second edition. 1996, pgs. 43, and 51-54.	12-41
Y, A	US 5,671,279 A (ELGAMAL) 23 September 1997, figures 1-4, col. 3, lines 38-42.	12-41

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Date of the actual completion of the international search 30 JULY 1999	Date of mailing of the international search report 09 SEP 1999
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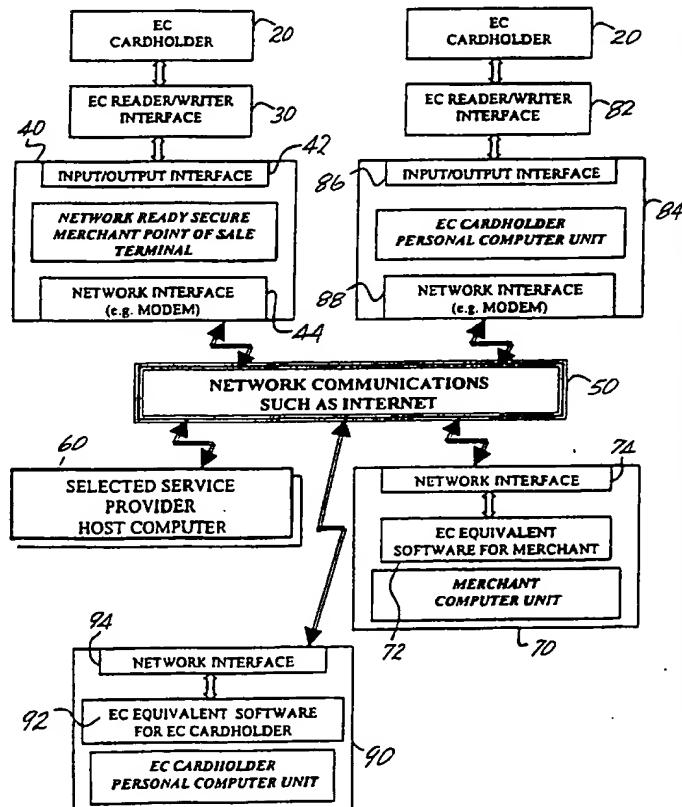
(51) International Patent Classification 6 :	A1	(11) International Publication Number: WO 99/57835
H04K 1/00, H04L 9/00		(43) International Publication Date: 11 November 1999 (11.11.99)

(21) International Application Number: PCT/US99/09938	(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
(22) International Filing Date: 5 May 1999 (05.05.99)	
(30) Priority Data: 60/084,257 5 May 1998 (05.05.98) US	
(71)(72) Applicant and Inventor: CHEN, Jay, C. [-/US]; 1335 Blackstone Road, San Marino, CA 91108 (US).	
(74) Agent: GELFOUND, Craig, A.; Christie, Parker & Hale, LLP, P.O. Box 7068, Pasadena, CA 91109-7068 (US).	
	Published <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>

(54) Title: A CRYPTOGRAPHIC SYSTEM AND METHOD FOR ELECTRONIC TRANSACTIONS

(57) Abstract

An electronic transaction system, which facilitates secure electronic transactions among multiple parties including cardholders (20), merchants (70), and service providers (SP) (60). The system involves electronic cards, commonly known as smart cards, and their equivalent computer software package. The card mimics a real wallet and contains commonly seen financial or non-financial instruments such as a credit card, checkbook, or driver's license. A transaction is protected by a hybrid key cryptographic system and is normally carried out on a public network such as the Internet. Digital signatures and random numbers are used to ensure integrity and authenticity. The card utilizes secret keys such as session keys assigned by service providers (SPs) to ensure privacy for each transaction. The SP is solely responsible for validating each participant's sensitive information and assigning session keys. The only trust relationship needed in a transaction is the one that exists between individual participants and the SP.



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BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakhstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

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A CRYPTOGRAPHIC SYSTEM AND METHOD FOR ELECTRONIC TRANSACTIONS

FIELD OF THE INVENTION

5 The present invention relates generally to a cryptographic system and method for secure electronic transactions, and more particularly to an electronic card, which takes the form of a "smart card" and/or its equivalent software.

BACKGROUND OF THE INVENTION

10 The generic term, "smart card," generally denotes an integrated circuit (IC) card, that is, a credit-card-size piece of plastic with an embedded microchip. The IC chip on a smart card generally, but not necessarily, consists of a microprocessor (the CPU), read-only memory (ROM), random access memory (RAM), an input/output unit, and some persistent memory such as electrically erasable programmable read-only memory (EEPROM). The chip can perform 15 arithmetic computations, logic processing, data management, and data communication.

Smart cards are mainly of two types: contact and contact-less. The International Standard Organization (ISO) has established specifications for such electronic cards under the ISO series. In particular, ISO 7816 applies to integrated circuit(s) cards. Because of its computing capability, a smart card can support a multitude of security features such as authentication, secured read/write, symmetric key and asymmetric key encryption/decryption. These smart card 20 security features make it well suited for electronic commerce where data security and authenticity are of primary importance.

Smart card use has found application in many specialized fields such as mass transportation, health insurance, parking, campus, gas, etc. And its potential use in electronic 25 commerce and other financial areas are gaining popularity at a rapid pace. U.S. Pat. No. 5,521,362, issued to Robert S. Power on May 28, 1996, entitled "Electronic purse card having multiple storage memories to prevent fraudulent usage and method therefor," describes an electronic purse application. Power's invention demonstrates a smart card's capability to be used as a secure financial instrument and not just as a storage device.

As advances in technology push smart-card chip computing to higher speeds and larger 30 memory capacity, the concept of a "multi-application" smart card is increasingly becoming economically and physically feasible. U.S. Pat. No. 5,530,232 issued to Douglas C. Taylor on June 25, 1996, entitled "Multi-application data card," describes a multi-application card, which is capable of substituting for a plurality of existing single-application cards and satisfying both 35 financial and non-financial requirements. The multi-application card uses a conventional data link to connect between the smart card and the remote service provider. Taylor's invention, the multi-application card, does not relate to any kind of open network or cryptographic method.

U.S. Pat. No. 5,544,246 issued to Mandelbaum et al. on Aug. 5, 1996, entitled "Smart

1 card adapted for a plurality of service providers and for remote installation of same," describes
a smart card, which allows different service providers to coexist on the same smart card. Each
service provider is considered a user of the smart card and is installed on the card by the
issuer/owner of the smart card. Each user is allowed to build a tree-like file structure and protect
5 it with a password file. Mandelbaum's invention depicts a smart card allows for the creation and
deletion of multiple applications. Mandelbaum's smart card controls the access to each
application by using an appropriate password file.

U.S. Pat. No. 5,671,279 issued to Taher Elgamal on September 23, 1997, entitled
"Electronic commerce using a secure courier system," describes a system for implementing
10 electronic commerce over a public network using public/private key cryptography. The Elgamal
patent did not mention the use of a smart card as a tool in conducting the electronic commerce
and the participants were authenticated through the use of digital certificates. The secure courier
system requires a secured channel such as a Secure Socket Layer (SSL) between the trading
parties over an open network such as the Internet.

15 1. U.S. Pat. No. 5,790,677, issued to Fox et al. on August 4, 1998, entitled "System
and method for secure electronic commerce transactions," describes a system and method
having a registration process followed by a transaction process. During the registration
phase, each participant of a transaction registers with a trusted credential-binding server
by sending to the server a registration packet. The server produces unique credentials
20 based upon the request received and sends them to the request originator. During the
transaction phase, the originator of the transaction requests, receives and verifies the
credentials of all intended recipients of the commerce document and/or instrument and
encrypts the document and/or instrument using the public key of the individual recipient.
Thus, each receiving party can decrypt and access the information intended only for him.
25 Fox's patent describes a process which reflects the theme of the so called "Secure
Electronic Transaction" (SET) standard which is an ongoing effort supported by several
major financial and software companies to establish a digital certificate and certificate
authority based electronic commerce system.

30 U.S. Pat. No. 5,796,840 issued to Derek L. Davis on August 18, 1998, entitled "Apparatus
and method for providing secured communication," describes a semiconductor device, which is
capable of generating device-specific key pairs to be used in subsequent message authentication
and data communication. The semiconductor device uses public/private key cryptography to
ensure the authenticity of two communicating parties.

35 U.S. Pat. No. 5,534,857 issued to Simon G. Laing and Matthew P. Bowcock on July 9,
1996, entitled "Method and System for Secure, Decentralized Personalization of Smart Cards,"
describes a method and apparatus for securely writing confidential data from an issuer to a
customer smart card at a remote location. A mutual session key for enciphering data transfer
between a secure terminal and a secure computer is generated by using a common key stored in

1 the secure computer and a retailer smart card.

It is clear from the inventions mentioned above that the architecture of a secure electronic commerce system involves a public key infrastructure and digital certificate authority associated with it.

5 On an open network, a secret key-based system is less flexible in terms of key distribution and key management, and is more subject to malicious attack. On the other hand, a public/private key-based system, with all its advantages over the secret key system, has its own daunting task of authenticating transaction parties to one another. The current invention presents another system and method, which replaces the need for certificate authorities and digital 10 certificates. The current invention is a hybrid system for electronic transactions. The hybrid system uses public/private keys during the key exchange phase and uses a session key as a secret key during the transaction phase.

SUMMARY OF THE INVENTION

15 The invention is a cryptographic system and method for electronic transactions by using an electronic card (EC) in the form of a smart card or equivalent software and communicating over a communications network.

20 The preferred embodiment of the invention uses an open network, such as the Internet. Alternative embodiments of the invention may use other types of networks. An embodiment of the invention may either use a physical smart card, or alternatively, a smart card, which is implemented as computer software package and runs on a computing device such as a personal computer (PC). Likewise, a merchant involved in a transaction may use a merchant device, which is a point-of-sale terminal, or a device, which uses software on a host computer to communicate with an EC and a service provider. When a smart card is used, a smart card reader 25 is also needed to allow the card to communicate with a host device, such as a network ready merchant terminal, a PC, or any other electronic device, which is capable of supporting smart card transactions.

30 In a public key and digital certificate based system, transaction participants exchange public information through the use of digital certificates or other electronic credentials which are issued and certified by a certificate authority (CA) or credential binding server. The communication between the CA or the server and each participant of the transaction must be secure. Random numbers and digital signatures are used to ensure the authenticity and validity 35 of the messages transmitted among the participants.

35 The cryptographic system and method of the preferred embodiment of the invention also uses public/private key cryptography, but it works in a slightly different way. The cryptographic system and method does not seek to create another kind of trust relationship as the one that exists between holders of digital certificates and the certificate authorities. It particularly targets large membership-based financial institutions such as a large credit card company and all its

1 cardholders, or a major bank and all its ATM cardholders as its potential users. Non-financial institution can also use this cryptographic system and method to conduct commercial or non-financial transactions over a network.

5 A service provider (SP) provides some service to its members. Financial institutions are just one kind of service provider. A service provider can also be non-financial in nature. Regardless whether a service provider is a financial institution or a non-financial institution, essentially the same process occurs. The only difference between a transaction involving a financial institution and a transaction involving a non-financial institution is that the messages may include different data fields.

10 When an EC holder signs up with one of the service providers, the service provider creates a dedicated entry on the EC. Each entry contains the account information for the service provider, the SP's public key, access control information, and other related data. Each EC can support a predetermined number (e.g. ten) of such entries and each such entry is a representation of one service provider.

15 By using the public/private key cryptography, the key distribution process is much simplified. The EC holder him/her/self or any trusted third party such as a bank branch or even a post office can perform the task. The SP's public key is only used for the initial key exchange between the SP and the cardholder. After the initial key exchange step, the SP assigns a session key, which protects any further message exchange between the cardholder and the SP or between 20 the cardholders' themselves.

25 This hybrid system, which uses both public key/private key cryptography and secret key cryptography (i.e., session key), is in contrast to other secret-key systems in that in the hybrid system, the secret key (i.e., session key) is valid for a single session and is not applicable to other sessions. A session has a determinate length of time. A session may terminate based upon a time period or upon conditions being satisfied.

30 Where a merchant is involved in a transaction, the merchant goes through essentially the same procedures as the EC holder to communicate with the SP. The merchant will first perform a key exchange with the SP and receive a session key. The session key will be used by the merchant for subsequent communication with the SP. The cardholder and the merchant digitally sign each message going to the SP and the SP similarly signs the response message going back to the cardholder and the merchant.

35 In the event that a transaction requires interactions with another certificate-based system, the SP, after authenticating the cardholder and the merchant based on further information exchange after the initial key exchange, can act as a surrogate-certificate for the cardholder and the merchant. In the most extreme case, the SP performs solely this surrogate function and becomes a gateway for the certificate-based system. This type of hierarchy is highly desirable since it reduces the number of trust relationships needed to carry out a transaction among multiple systems. In addition, it eliminates the users' need to carry certificates.

1

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram showing the relationship among the components of a system according to an embodiment of the invention.

5

Figure 2 shows the flow of the two transaction phases via a network.

Figure 3 is the diagrammatic representation of an EC.

Figure 4 shows the format of the service provider data area. Each service provider's information is allocated an entry in the table and is protected by access conditions.

Figure 5 shows how the digital signatures are used in an embodiment of the invention.

10

Figures 6A through 6Q shows the schematic flow chart of the cryptographic system and method used in an embodiment of the invention in order to conduct electronic transactions via an open telecommunication network, such as the Internet.

Figure 7 through Figure 11 depicts the final format and content of the combined request and response messages in the key exchange phase and the transaction phase.

15

Figure 12 shows a service provider conducting a transaction with participants that have been arranged in series.

Figure 13 shows a service provider transaction on a network with participants that have been arranged in a hierarchical organization scheme.

20

DETAILED DESCRIPTION

The preferred embodiment of the invention is a cryptographic system and method for electronic transactions by using an electronic card (EC) in the form of a smart card or equivalent software and communicating over a communications network.

25

In the preferred embodiment of the invention, the network is an open network such as the Internet. In alternative embodiments of the invention, other open networks and/or closed networks may be used to establish communication between a service provider and its members. For example, a service provider may use its own proprietary financial network to communicate with its members.

30

Any Internet protocol may be used for Internet connections. Example protocols, which can be used include TCP/IP, UDP, HTTP, and the like.

35

Communication may also be via a communications network transport service such as the Public Switched Telephone Network (PSTN) using traditional analog telephone service (a.k.a. Plain Old Telephone Service or POTS), or by using a digital communication service such as a T-1, E1 or DS-3 data circuit, Integrated Services Digital Network (ISDN), Digital SubscriberLine (DSL) services, or even using a wireless service, and the like. When implemented using such a service the invention may be implemented independent of a communications protocol (i.e. at an electrical interface layer).

1 Communication may also be via a local area network (LAN) or WideArea Network
5 (WAN) such as Ethernet, Token Ring, FDDI, ATM or the like. Example protocols, which
can be used include TCP/IP, IPX, OSI, and the like.

5 Other communication links might include an optical connection, a wireless RF modem
connection, a cellular modem connection, a satellite connection, etc.

10 The invention may be employed as long as a communication path can be established
between a service provider and its members. The examples above are intended to illustrate
several examples of the various communications environments in which the invention may be
practiced. As is clear to one ordinarily skilled in the art, the invention is not limited to those
environments detailed above.

15 The EC can take the form of a smart card device or a software package running on a
computer system such as a personal computer (PC). When the EC is implemented on a smart
card, it can be used on a network-ready computer system such as a PC to transact with another
member and/or a selected service provider. It will need a read/write interface device to
communicate with a computer system and some application software such as an Internet browser
20 to interface with the cardholder and the network. If the EC is a software package loaded into a
computer system, then no read/write interface is needed. The exemplary embodiment of the
invention is for the EC to act as an electronic wallet (or cyber wallet) which functions similar
to real wallet. A real wallet can carry credit cards, debit cards, ATM cards, health provider
cards, membership cards, cash, etc. An EC has the digital equivalent of all the above-mentioned
financial and non-financial instruments and enables conducting secure transactions over the
Internet.

25 A service provider member can be a merchant and/or an EC cardholder. A merchant is
a member who is paid by the service provider as a result of a transaction. A member can be both
a merchant and an EC cardholder. A merchant may engage in a transaction with other
cardholders, which results in the merchant being paid by the service provider. A merchant may
also be an EC cardholder and purchase supplies, for example, from a merchant supplier.

30 The cryptographic system may involve communication between a service provider and
any number of service provider members. Thus, communication can be between an EC and an
SP, between a merchant and an SP, between a first EC, a second EC, and an SP, between a first
merchant, a second merchant, and an SP, etc. An EC may communicate directly with a service
provider to inquire about an account balance for example. A merchant may communicate with
35 a service provider only on his own behalf and not on behalf of an EC because, for example, the
merchant wants to know his own account balance with the service provider. Communication
between the SP and its members may follow any permutation of the SP and its members. The
organization of the communication links between the SP and its members may be sequential
and/or hierarchical. Communication between the SP and its members may also be via routers,
which route the messages between the SP and its members.

1 The cryptographic method is a two-phased key-exchange-transaction model. The first
phase is a key exchange phase. The second phase is the transaction phase. In the key exchange
phase, the members exchange keys with the service provider. The members send their keys to
the service provider and the service provider uses the keys to send a session key to the members.
5 The session key protects any further message exchange between the cardholder and the SP or
between the cardholders' themselves. In the transaction phase, either the SP can direct the
transaction or the cardholders themselves may conduct the transaction.

10 Figure 1 is a block diagram showing the relationship among the components of a system
according to an exemplary embodiment of the invention involving a cardholder, a merchant, and
service provider.

15 An EC cardholder 20 can conduct a transaction over a network 50 and communicate with
a merchant either by using an EC read/write device 82 attached to an originating computer 84
or by using EC equivalent software 92 running on an originating computer unit 90.

20 A merchant can conduct a transaction over a network by either using a network-ready
point-of-sale(s) (POS) terminal 40 or by using EC equivalent software running on a merchant
device 70 to conduct an electronic transaction with a selected service provider 60 via a network
50 such as the Internet.

25 Once the access conditions to the card have been satisfied, the cardholder can perform
financial or non-financial transactions with other participants of the system through the network
50. In Figure 1, there are three different scenarios in which a transaction over a network can be
conducted.

- (1) In a POS transaction (Upper left side of figure 1), the cardholder 20 swipes/inserts an
EC through/into a merchant's EC reader/writer 30 at a merchant's premises. The EC
reader/writer is connected to a network-ready merchant POS terminal 40. The network-
ready merchant POS terminal 40 is a secure tamper-resistant programmable device
comprising an input means such as a keyboard, a display device, a processing unit, and
an EC read/write device 30 (an EC interface device). It is typically a small computer
unit such as a PC equipped with a communication link to an open network. The POS
terminal communicates to the SP via the network 50.
- (2) (Right side of figure 1) A cardholder can conduct a transaction with other participants
of the system by inserting the EC 20 into a read/write device 82, which is connected to
the cardholder's personal computer 84 which is the originating computer. The
originating computer connects to a network 50 allowing the EC to communicate with
the merchant computer unit 70. The merchant computer unit 70 has EC equivalent
software 72 that enables the merchant to receive the EC generated message and
generates a message combining EC information and merchant information. Then, the
combined message is sent to the SP over a network.
- (3) (Bottom side of figure 1) A cardholder can conduct a transaction with other participants

1 of the system by using EC equivalent software 92 on the customer cardholder's personal computer 90. The transaction begins at the originating computer unit 90, that is, the cardholder's personal computer. The cardholder conducts the transaction over a network 50 and communicates with the merchant's computer unit 70, which in turn 5 communicates with the SP 60 over a network 50.

While in the preferred embodiment of the invention, a personal computer is used to hold the EC equivalent software, in alternative embodiments of the invention other electronic devices can be used to hold the EC equivalent software.

In the preferred embodiment of the invention, the network used to enable the EC to communicate with the merchant is the same network used to enable the merchant to communicate with the SP. In another embodiment, the network used to enable the EC to communicate with the merchant may not be the same network used to enable the merchant to communicate with the SP. In yet another embodiment, the network used to enable one merchant to communicate with the SP may not be the same as the network used to enable another merchant to communicate with the SP. In still yet another embodiment, the network used to enable an EC to communicate to the merchant may not be the same as the network used to enable another EC to communicate with another merchant. An embodiment may consist of a multiplicity of networks whereby different parties communicate.

In the preferred embodiment of the invention, a transaction is broken down into two phases: a key exchange phase and a transaction phase. Figure 2 is a specific case, which illustrates the two-phase key-exchange-transaction model where the SP directs the transaction phase. There is no direct exchange of sensitive information between participants when the SP directs the transaction.

The key exchange phase is the same where the transaction phase is among the cardholders themselves and where the SP directs the transaction phase. Where the transaction phase is among the cardholders themselves, the cardholders use the SP session key to communicate with each other and conduct a transaction.

Figure 2 demonstrates a financial transaction where the SP directs the transaction phase. The transaction shown involves three parties: an EC (a transaction originator) 102, a merchant 104, and a service provider (SP) 106. The originating party is an EC cardholder who is the consumer and is represented by the computer unit 102. The computer unit 104 represents the merchant. The computer unit 106 represents the service provider. An SP is selected by both an EC and merchant.

Figure 2 demonstrates a financial transaction wherein the process flow is from an EC to a merchant to an SP. The cryptographic method's process flow is not limited to any particular order between merchants and EC cardholders. Figure 2 is merely an example of a particular transaction, which flows from EC to merchant to service provider. The process flow can also go from merchant to EC to service provider. Figure 2 demonstrates how service provider

1 members (in this case, the EC cardholder and the merchant) create, append, and send messages
to a service provider.

5 The ten arrows numbered 1 to 10 in figure 2 show how the messages flow among the three parties during the two transactions phases. Steps 1 through 4 belong to the key exchange phase and steps 5 through 10 belong to the transaction phase. In figure 2, the merchant serves as an intermediary between the EC and SP. In step 1, the key exchange request is formatted by the EC and sent to merchant. In step 2, the merchant combines his own key exchange message with the EC's key exchange message and sends the combination key exchange message to an SP. In step 3, the SP formats a key exchange response for the merchant, formats a key exchange response for the EC, combines the key exchange responses to form a combined key exchange response and sends the combined key exchange response to the merchant. In step 4, the merchant separates the key exchange response for the merchant from the key exchange response for the EC and forwards the EC's key exchange response message back to the EC. Step 4 concludes the main activities in the key exchange phase.

10 The transaction phase begins with step 5. In step 5, the EC formats its transaction request message and sends it to merchant. In step 6, the merchant combines the received transaction request message with his own transaction request message and sends the combination transaction request message to the SP. In step 7, the SP formats a transaction response message for the merchant, formats a transaction response message for the EC, combines the transaction response messages and sends the combined transaction response message back to merchant. In step 8, the merchant separates the transaction response message for the merchant from the transaction response message for the EC and forwards the EC's transaction response message back to the EC. In step 9, the EC formats a confirmation message and sends it to the merchant. In step 10, the merchant combines the received confirmation message with his own confirmation message and sends the combination confirmation message the SP. Step 10 concludes the transaction phase of a transaction.

15 While figure 2 demonstrates a simple transaction, some transactions may involve multiple messages. During some transactions, more than one message may be required to complete each phase, in which case, those messages will follow the same rules of combination and flow pattern. 20 For example, during the transaction phase, the SP may require that the EC and the merchant send over account information first. If the account information is verified to be valid, the SP sends confirmation of the account information in the response message. Once the merchant and the EC receives the response message, then the EC and the merchant send the transaction amount and other transaction related information in the next message going to the SP. The SP subsequently approves or disapproves the transaction. The steps in figure 2 apply to both the 25 account message and the transaction message.

30 If the completion of a transaction requires interaction with some external system such as a public key and digital certificate based system 108, the SP will act as a surrogate-certificate

1 for the EC and the merchant and deal with the external system on behalf of the EC and the
merchant. A desired result of the invention is to shield all of the participants of a transaction
from an external system and therefore reduce the number of trust relationships needed to
complete a transaction. If a participant of a transaction has dual membership of this system and
5 an external system, then he has a choice of either acting as a member of this system or as a
member of an external system. In the latter case, the SP will interface with the participants using
the rules of an external system. For example, to deal with an external public and digital
certificate or credential based system, the SP has in its possession all of the required certificate(s)
10 or credential(s) which satisfies the trust relationship demanded by the external system. Such
credentials are required in order for the SP and the external system to complete the transaction
initiated by the EC and the merchant. In this case, only the SP needs to have a trust relationship
with the external system. Based on this trust relationship, individual ECs and merchants are able
to complete transactions with the hypothetical external system.

15 Figure 3 is a diagrammatic representation of a preferred embodiment of an EC. In a
preferred embodiment of the invention, an EC is internally composed of the software/hardware
components shown in Figure 3. The EC is ISO 7816-based and supports the same kind of
communication protocols and commands as defined in ISO 7816.

20 The EC has a card operating system 550 to manage the EC's internal resources. The on-
card cryptographic service 650 can be implemented in software or be provided by a
cryptographic co-processor (not shown in figure 3), or other hardware solutions, or a hybrid of
software and hardware.

25 One of the unique features of the EC is the service provider data area (SPDA) in the EC
memory, which contains the service providers' account and key information. The service
provider data area (SPDA) 700 contains a number of slots. In the preferred embodiment, the
SPDA contains a pre-defined number (e.g. ten) of slots -- one for each potential service provider.
In another embodiment, the number of slots may be dynamically changed. A record for each
30 service provider can be placed into an empty slot. Each record contains the account number,
public key, and other related information for a specific service provider.

35 Depending on the EC design, the SPDA can optionally allow each SP to include some
software (such as an "applet" in the JAVA terminology) to manage its own on-card data and
provide an interface between the SP card data and the host application. In other words, the SPDA
can contain more than just simple data; it can allow each SP to put a self-contained application
program (such as an applet) on the EC to provide its own unique service to the cardholder. The
advantage of this type of design is that the EC itself is now detached from the type of service it
can provide. Each SP can bring with it its own service capability. When another SP replaces
an on-card SP, there will be no change necessary to the EC platform. The new SP applet is
simply loaded into the card and it will perform what it is designed to do.

In the SPDA, each service provider is allocated space for public keys. In many transactions,

1 only one key pair is used, but for some online transactions, two or more key pairs are required.
If the SP uses the same public/private key pair for both the incoming and the signing of outgoing
messages, then one public key is enough. If the SP uses a different key pair for signing, then
both SP public keys (one for incoming messages and one for the signing of outgoing messages)
5 are required in the SPDA.

10 In the preferred embodiment of the invention, two public/private key pairs rather than one
public/private key pair is used to communicate with other applications through a network
because using two public/private key pairs rather than one public/private key pair provides
greater security. One pair is used for decrypting an incoming message, i.e., the sender encrypts
the message using the recipient's public key and the recipient decrypts the message using the
corresponding private key. The other pair is for the sender to digitally sign the message he sends
out and the recipient to verify the digital signature using the corresponding sender's public key.

15 Each service provider is allocated space for the number of public keys used by the service
provider. If the SP uses the same public/private key pair for both incoming messages and
signing of outgoing messages, then one public key is enough. If the SP uses different key pairs
for receiving and signing messages, then both of the SP's public keys are required in the SPDA.

In an alternative embodiment of the invention, more than two public/private key pairs may
be required and used by a service provider for even greater security.

20 When an EC holder is issued a new financial or non-financial instrument, the issuing
institution or a trusted third party will load the needed information comprising a record into an
available slot. The information in the slot can be erased when the service provider account is
closed. Some of the information in a slot can be read and modified during a transaction, e.g. an
account balance. Some information such as account number is write protected, but can be read.
Some information such as a private key is both read and write protected. The access conditions
25 600 contain security information such as PINs, biometric data, etc., that an EC user must submit
to open the card for use or to gain access to the information stored on the card.

30 Traditional Personal Identification Numbers (PINs) or other security measures such as
biometrics data are used to protect the EC. Biometrics involves the measurement of a
cardholder's biological traits, such as physical traits and behavioral traits. A biometric system
may measure an individual's fingerprints, hand-geometry, hand writing, facial appearance,
speech, physical movements, keyboard typing rhythms, eye features, breath, body odor, DNA,
or any other physical attribute of the cardholder. The functions provided by an EC can be
activated only after all the access conditions have been satisfied. Each service provider residing
on the card can optionally implement other access conditions.

35 Figure 4 shows the format of the service provider data area of a preferred embodiment of
the invention. Each service provider's information is allocated an entry in the table, which can
be protected by additional access conditions. The PIN 712 and the miscellaneous data field 714
allows the service provider to provide extra protection or data field to the instrument it supports.

1 The name field 702 contains the names of the service providers, which can be used by the
cardholder at the beginning of an online transaction to initially select the applicable service
provider for a transaction. The key type field 704 specifies the type of key the service provider
chooses to use, secret key, public key, etc. The key value 706 and account information fields
5 708 contain information unique to each service provider. The card type field 710 specifies the
type of instrument a service provider supports.

In the preferred embodiment of the invention, the on-card Operating System (COS)
provides some fundamental services for the cardholder. Following is a list of general functions
which can be performed by the COS:

- 10 (1) Traditional OS functionality such as Memory management, task management, etc
 (2) External communication-read/write of user data and communication protocol handling.
 (3) Loading and updating of on-card cardholder information.
 (4) User PIN changes.
15 (5) Service Provider Data Area management-such as loading and updating of individual service
 provider information, SPDA access control, etc.

The COS will also provide support during various stages of a transaction. For example, the
COS can handle the SP selection at the beginning of a transaction and record the transaction into
20 a log file when the transaction has been completed. An embodiment of the invention may
implement one of the following two design approaches to the COS or a hybrid of the two design
approaches:

- 25 (1) Most of the intelligence can be put into the COS whereby the COS supports most of the EC
 functionalities. Consequently, each on-card service provider area relies on the COS to carry
 out the transaction with the merchant and the SP. In this approach, the COS can provide
 a uniform interface with the outside world for all on-card SPs and efficiently carries out the
 transaction once a SP has been selected.
30 (2) Alternatively, the COS can be a pool of general services each on-card SP can utilize. Each
 SP data area can contain applets, which have the intelligence to carry out a transaction with
 the merchant and the SP. In this approach, the SP has more opportunity to implement its
 own unique feature when performing a transaction.

Figure 5 shows how digital signatures are used in the preferred embodiment of the
invention. A sender of a message first prepares and sends the data portion of a message M 900
35 through a one way hash algorithm, H(*) 902. The output from the hash algorithm is called the
 message digest MD of message M 903. The MD is then encrypted, E(*) 904, i.e. digitally signed,
 using the sender's private key (Pri). The result is called the digital signature DS of a message M.
 The DS is then combined with the original message M 900 and forms a complete message 906
 ready for transmission to a recipient through a network 50.

1 The public-key encryption/decryption function can be any of a number of
5 encryption/decryption functions. RSA, which takes its name from the first initials of RSA
developers' last names (Ronald Rivest, Adi Shamir, and Len Adelman), is just one example of
invention.

10 When the intended recipient receives the message from a network 50, he first separates the
data portion of the message M 900 from the digital signature 912 combined with it. The
recipient then runs the data portion of the message M 900 through the same hash algorithm 910
that was used to encode the data portion of message M 900, and consequently obtains a message
digest MD[^] 911 of M. The recipient then decrypts D(*) 908 using the EC's public key, the
digital signature 912 contained in the original message using the sender's public key and
recovers the original message digest, denoted here as MD 909. MD 909 is compared with the
new calculated MD[^] 911 for correctness. If they are not identical, the original message has been
corrupted and should be rejected.

15 Following is a list of symbols and abbreviations used in the figures 5 through 11:
Acknowledgement Data_{EC} = A part of the message sent back by the EC to the SP. It notifies the
SP that the previous message has been successfully received and processed.
Acknowledgement Data_M = A part of the message sent back by the merchant to the SP. It
notifies the SP that the previous message has been successfully received and processed.
AI_{EC} = Account information of EC holder.
AI_M = Account information of merchant.
CRYPTO = Cryptogram
D = Decryption function
25 **D**_{SP-Private-Key} = Decryption using SP's private key.
DS = Digital signature function.
DS_{EC-Private-Key} = Digital signature signed by the EC on a message.
DS_{M-Private-Key} = Digital signature signed by the merchant on a message.
DS_{SP-Private-Key} = Digital signature signed by the SP on a message.
30 **E** = Encryption function.
E (Data) = Encryption of data under a data encryption key.
E_{SP-PK}, **E**_{SP-Public-Key} = Data encrypted by SP public key
E_{Skey-EC}, **D**_{Skey-EC} = Encryption/Decryption using the session key that the SP generated for the EC.
35 **E**_{Skey-M}, **D**_{Skey-M} = Encryption/Decryption using the session key that the SP generated for the
merchant.
EC = Electronic card, or electronic card equivalent software
H (M) = Apply a one-way hashing algorithm on M. It generates the message digest (**MD**) of M.
KE = Key exchange phase.

- 1 M = Merchant
MD = Message Digest
 MD^{\wedge} = Message Digest produced by message recipient using the message just received as input data.
- 5 MD_{EC} = The message digest of a message going from EC to SP.
 MD_M = The message digest of a message going from merchant to SP.
 MD_{SP-M} = The message digest of a message going from SP to merchant.
 MD_{SP-EC} = The message digest of a message going from SP to EC which is bypassed by merchant.
- 10 PLAIN TEXT: Transaction data, which can be transmitted without encryption. Plain text can be different for different messages and transaction parties.
 $PLAIN\ TEXT_{EC}$ = Part of the transaction data provided by EC in its outgoing messages. Plain text data fields are not security sensitive. Therefore, they are transmitted without encryption. Note that the content of this symbol can be different when used in a different message.
- 15 $PLAIN\ TEXT_M$ = Part of the transaction data provided by merchant in its outgoing messages. Plain text data fields are not security sensitive. Therefore, they are transmitted without encryption. Note that the content of this symbol can be different when used in a different message.
 $PLAIN\ TEXT_{SP-EC}$ = Part of the transaction data provided by SP for EC only in its outgoing messages. Plain text data fields are not security sensitive. Therefore, they are transmitted without encryption. Note that the content of this symbol can be different when used in a different message.
- 20 $PLAIN\ TEXT_{SP-M}$ = Part of the transaction data provided by SP for merchant only in its outgoing messages. Plain text data fields are not security sensitive. Therefore, they are transmitted without encryption. Note that the content of this symbol can be different when used in a different message.
- 25 STD = Sensitive transaction data, which requires encryption during data transmission.
 STD_{EC} = Sensitive transaction digital data provided by EC in its outgoing messages. Note that the content of this symbol can be different when used in a different message.
- 30 STD_M = Sensitive transaction digital data provided by merchant in its outgoing messages. Note that the content of this symbol can be different when used in a different message.
PK = Public key
 $EC-PK, PK_{EC}$ = Public key of the electronic card.
 $M-PK, PK_M$ = Public key of the merchant.
- 35 $SP-PK, PK_{SP}$ = Public key of the selected service provider.
 $Response\ Data_{SP-EC}$ = A part of the message sent back by the SP to the EC during the transaction phase of a transaction. It can include approval/disapproval data and/or any other relevant data.
 $Response\ Data_{SP-M}$ = A part of the message sent back by the SP to the merchant during the

1 transaction phase of a transaction. It can include approval/disapproval data and/or any other relevant data.

RN = Random number.

RN_{EC} = Random number generated by the EC and is sent to SP.

5 RN_{SP-EC} = Random number generated by the SP and is sent to EC.

RN_M = Random number generated by the merchant.

RN_{SP-M} = Random number generated by the SP and is sent to M.

SP = Financial or non-financial service provider

TA = Transaction (currency) amount.

10 Transaction Identification Number_{SP-EC}, TID_{SP-EC} (Transaction ID_{SP-EC}) = A data field whose value is assigned by the SP during the key exchange phase of a transaction. The EC will use this value to communicate with the SP during the same transaction.

15 Transaction Identification Number_{SP-M}, TID_{SP-M} (Transaction ID_{SP-M}) = A data field whose value is assigned by the SP during the key exchange phase of a transaction. The merchant will use this value to communicate with the SP during the same transaction.

* = Combine or concatenation of data within an encryption E or a decryption D.

20 Figures 6A through 6Q comprise the flowchart for a preferred embodiment of the cryptographic system and method. For the purpose of simplifying the description and symbolism contained in figures 6A through 6Q, the flowchart assumes that each of the parties involved in the transaction uses one key pair. In another embodiment of the invention, two public key pairs may be used, in which case, both public keys need to be exchanged.

The preferred embodiment of the invention consists of two distinct phases: the key exchange phase and the transaction phase.

25 PHASE I: KEY EXCHANGE PHASE (HANDSHAKE PHASE)

The EC cardholder inserts the EC into a card read/write device or starts the EC equivalent software and enters a PIN number and/or satisfies the access conditions 110 to use the EC card. The entered security information conditions is compared 112 with the on-card information 114 to verify that user is authorized to use the EC. If the security information does not match the card security information, then the request to use the card is rejected 116. Otherwise, the card is unlocked 118 for use. Once the card is unlocked, the user can request the list of the on-card SPs available for selection and make a selection 120 by issuing an SP selection command to the EC. Once the SP is selected, the EC proceeds to start the key exchange (KE) with the SP. The public key of the selected SP, represented by the symbols SP-PK and PK_{SP}, is obtained from the EC's SPDA and is used to encrypt messages that will be sent to the SP.

30 The main purpose of the KE is to securely send the cardholder's public key, PK_{EC} 126 and an EC random number, RN_{EC} 124 to the SP. The SP response to the EC is to assign a session key and a transaction ID to the EC, which will be used by the EC to communicate with the SP for the

1 rest of the transaction. To format the KE message, the EC generates a random number, RN_{EC} 124, concatenates it with the EC's public key, PK_{EC} 126, and EC sensitive transaction data STD_{EC} 128 relevant to the transaction and/or required by the SP. The EC encrypts them 122 using the SP's public key, PK_{SP} , retrieved from the SPDA 120. The resulting EC cryptogram, 5 $E_{ES-PK}(RN_{EC}*PK_{EC}*STD_{EC})$, is then combined 130 with the plain text portion of the message, PLAIN TEXT_{EC} 132, if any, to form an EC combination message, PLAIN TEXT_{EC}* $E_{SP-PK}(RN_{EC}*PK_{EC}*STD_{EC})$. The EC's public key PK_{EC} 126 may be placed in the plain text PLAIN TEXT_{EC} instead of being encrypted when forming the EC combination message.

Only sensitive data is encrypted. Non-sensitive response data is included in the plain text. 10 Only the SP is able to read the sensitive data. In a multi-party transaction, the SP has full access to the sensitive information of all the participants.

The resulting EC combination message is then sent through a hashing algorithm 134 to form a hash message, which is the EC message digest MD_{EC} . The EC message digest MD_{EC} is 15 digitally signed by the EC 136 using the EC private key 138 to form a digitally signed message DS_{EC-Private-Key}. The digitally signed message DS_{EC-Private-Key} is then combined 140 with the EC combination message. The combination of the plain text PLAIN TEXT_{EC}, cryptogram CRYPTO_{EC} and the digital signature DS_{EC-Private-Key} is the KE message from the EC and is sent to the merchant 158 through a network. Plain text includes all the transaction data fields that are 20 not sensitive in nature and therefore can be transmitted in a clear, discernable form; they do not need to be encrypted. These data fields are different for each message and are defined by the transacting parties.

To communicate with the SP, the merchant goes through essentially the same steps to format its own KE message with the SP as the EC goes through to format the EC's KE message with the merchant. The cardholder and the merchant do not communicate with the SP 25 individually, but through a combined message. Consequently, there will be no need to exchange any confidential financial information between the cardholder and the merchant. The merchant prepares his device for the transaction 142 and selects from his own SPDA, which resides within the merchant's device, the same SP as the EC cardholder has selected for the transaction 144. The public key of the SP, represented by the symbols SP-PK and PK_{SP} , is obtained from the SP's 30 SPDA and is used to encrypt messages that will be sent to the SP.

To format its own KE message, the merchant generates a random number, RN_M 148, concatenates it with the merchant's public key, PK_M 150, and the merchant's sensitive transaction data STD_M . Sensitive transaction data is data that is relevant to the transaction and/or required by the SP 152. The merchant encrypts 146 the combined data using the public key of 35 the service provider, PK_{SP} . The resulting cryptogram is then combined 154 with the plain text portion PLAIN TEXT_M 156 of the message, if any, to form a merchant combination message. The merchant's public key PK_M 150 may be placed within the plain text PLAIN TEXT_M instead of being encrypted when forming the merchant combination message PLAIN TEXT_M* E_{SP} .

1 $\text{PK}(\text{RN}_M * \text{PK}_M * \text{STD}_M)$.

The merchant combination message $[\text{PLAIN TEXT}_M * E_{\text{SP-PK}}(\text{RN}_M * \text{PK}_M * \text{STD}_M)]$ is further combined 158 with the EC's KE message $\{[\text{PLAIN TEXT}_{EC} * E_{\text{SP-PK}}(\text{RN}_{EC} * \text{PK}_{EC} * \text{STD}_{EC})] * DS_{EC-Private-Key}\}$ to form the data portion of the KE message for both the merchant and the EC, i.e., the
 5 EC-merchant combination message $\{[\text{PLAIN TEXT}_{EC} * E_{\text{SP-PK}}(\text{RN}_{EC} * \text{PK}_{EC} * \text{STD}_{EC})] * DS_{EC-Private-Key} * [\text{PLAIN TEXT}_M * E_{\text{SP-PK}}(\text{RN}_M * \text{PK}_M * \text{STD}_M)]$. The EC-merchant combination message is sent through a hashing algorithm 160 to form a hash message, which is the merchant message digest MD_M . The merchant message digest MD_M is digitally signed 162 by the merchant using the merchant's private key 164 to form a merchant digitally signed message $DS_{M-Private Key}$. The merchant digitally signed message $DS_{M-Private Key}$ is then combined 166 with the data portion of the message, i.e., the EC-merchant combination message to form a key exchange request message $<< \{ [\text{PLAIN TEXT}_{EC} * E_{\text{SP-PK}}(\text{RN}_{EC} * \text{PK}_{EC} * \text{STD}_{EC})] * DS_{EC-Private-Key} * [\text{PLAIN TEXT}_M * E_{\text{SP-PK}}(\text{RN}_M * \text{PK}_M * \text{STD}_M)] >> * DS_{M-Private-Key}$ for both the merchant and EC. This final message is sent to the SP through a network. Figure 7 represents the final format and content of the key exchange request message from a merchant to an SP.

In the preferred embodiment of the invention, the merchant does not check the MD of the EC's request message MD_{EC} because the EC encrypts his public key. However, in an alternate embodiment of the invention, if the EC chooses not to encrypt his public key then the merchant can optionally check the EC's MD before passing it to the SP. In either the case where the EC encrypts his public key or where the EC does not encrypt his public key, for enhanced security and to avoid possible processing errors by the merchant, the SP can still check the EC's MD. When the merchant receives a combination response from the SP for both himself and the EC, the merchant does not have to check the MD for the EC since it is part of the overall message formed by a single originator -- the SP. The merchant only needs to check the MD of the overall message he receives from the SP.

When the SP receives the KE request message, the SP first separates 168 the data portion of the KE request message from the DS and feeds the data portion of the KE request message into a one-way hash algorithm to recalculate the message digest, which becomes MD_M . The SP then separates the merchant's plain text PLAIN TEXT_M , cryptogram CRYPTO_M , digital signature $DS_{M-Private-Key}$ and the EC's KE request message $\text{PLAIN TEXT}_{EC} * \text{CRYPTO}_{EC} * DS_{EC-Private-Key}$. Using its own private key, the SP decrypts merchant's cryptogram 170 and recovers, among other information, the merchant's random number RN_M 148 and the merchant's public key PK_M 150. The SP then uses the recovered PK_M to decrypt the digital signature signed by the merchant $DS_{M-Private-Key}$ and recovers the MD_M for the merchant's KE message. The SP compares 172 the newly hashed MD^M_168 with the MD_M 170 recovered by decrypting the DS from the original KE message. If there is a discrepancy between MD^M_168 and MD_M found, then the KE message has been corrupted and is therefore rejected 174. If MD^M_168 and MD_M match, then the SP separates the data portion of the EC's KE request message from the DS and feeds the data

1 portion of the EC's KE request message into a one-way hash algorithm to recalculate the
message digest (MD^{EC}). The SP then separates the EC's plain text $\text{PLAIN TEXT}_{\text{EO}}$ if any,
5 cryptogram $\text{CRYPTO}_{\text{EC}}$, and digital signature $DS_{\text{EC-Private Key}}$ in the data portion of the EC's KE
request message 176. Using its own private key, the SP decrypts EC's cryptogram and recovers,
among other information, EC's random number RN_{EC} and EC's public key PK_{EC} . The SP then
uses the recovered PK_{EC} to decrypt the digital signature signed by EC and recovers the MD_{EC} for
EC's KE message. In the step 178, SP compares the newly hashed MD^{EC} 176 with the MD_{EC}
recovered by decrypting the DS from the original KE message. If there is any discrepancy
found, the KE message has been corrupted and is therefore rejected 180. Otherwise, SP is ready
10 to send a KE response message back to merchant and EC.

To format the KE response message for the EC, the SP generates a random number, $RN_{\text{SP-EC}}$
184, and a session key $Skey_{\text{EC}}$ 186 for the EC, combines them with the EC generated random
number, 188 RN_{EC} , service provider sensitive transaction data $STD_{\text{SP-EC}}$ 190 and encrypts them
192 using the EC's public key PK_{EC} . The resulting cryptogram,
15 $E_{\text{EC-PK}}(RN_{\text{EC}} * RN_{\text{SP-EC}} * Skey_{\text{EC}} * STD_{\text{SP-EC}})$, is combined 196 with a transaction identification
number, $TID_{\text{SP-EC}}$ 194 assigned to the EC by the SP and plain text, $\text{PLAIN TEXT}_{\text{SP-EC}}$ 195, if any,
to form the data portion of the response message for the EC. The SP runs this data through a
hash algorithm to calculate the message digest $MD_{\text{SP-EC}}$ 198. Using its own private key 202, the
20 SP creates a digital signature $DS_{\text{SP-Private-Key}}$ 200 for the response message by digitally signing the
message digest $MD_{\text{SP-EC}}$. After combining 204 the data portion of the message with the newly
calculated $DS_{\text{SP-Private-Key}}$, the SP's KE response message for the EC is complete,
 $[TID_{\text{SP-EC}} * \text{PLAIN TEXT}_{\text{SP-EC}} * E_{\text{EC-PK}}(RN_{\text{SP-EC}} * RN_{\text{EC}} * Skey_{\text{EC}} * STD_{\text{EC}})] * DS_{\text{SP-Private-Key}}$.

To format the KE response message for the merchant, the SP generates a random number
25 $RN_{\text{SP-M}}$ 208 and a session key $Skey_{\text{M}}$ 210 for the merchant and combines them with the merchant
generated random number RN_{M} 212, sensitive transaction data $STD_{\text{SP-EC}}$ 214 and encrypts them
206 using the merchant's public key PK_{M} recovered in 170. The resulting cryptogram is
combined 216 with a transaction identification number, $TID_{\text{SP-M}}$ 218, assigned to the merchant
by the SP and plain text, $\text{PLAIN TEXT}_{\text{SP-M}}$ 220, if any, to form the data portion of the response
message for merchant. The resulting combination message, $TID_{\text{SP-M}} * \text{PLAIN}$
30 $\text{TEXT}_{\text{SP-M}} * E_{\text{M-PK}}(RN_{\text{SP-M}} * RN_{\text{M}} * Skey_{\text{M}} * STD_{\text{SP-M}})$ is further combined 222 with the KE response
message for the EC, $[TID_{\text{SP-EC}} * \text{PLAIN TEXT}_{\text{SP-EC}} * E_{\text{EC-PK}}(RN_{\text{SP-EC}} * RN_{\text{EC}} * Skey_{\text{EC}} * STD_{\text{EC}})] * DS_{\text{SP-}}$
 Private-Key , to form the data portion of the SP's final KE response message, $[TID_{\text{SP-EC}} * \text{PLAIN}$
 $\text{TEXT}_{\text{SP-EC}} * E_{\text{EC-PK}} * (RN_{\text{SP-EC}} * RN_{\text{EC}} * Skey_{\text{EC}} * STD_{\text{EC}}) * DS_{\text{SP-Private-Key}} * [TID_{\text{SP-M}} * \text{PLAIN TEXT}_{\text{SP-}}$
 $\text{M}} * E_{\text{M-PK}}(RN_{\text{SP-M}} * RN_{\text{M}} * Skey_{\text{M}} * STD_{\text{SP-M}})]$. The SP runs the data portion through a hash algorithm
35 to calculate the message digest 224. Using its own private key 228, the SP creates a digital
signature, $DS_{\text{SP-Private-Key}}$ 226, for the response message by digitally signing the message digest.
After combining 230 the data portion of the message with the newly calculated DS 226, the KE
response message for both the EC and the merchant is complete. The response message

1 <<{[TID_{SP-EC}*PLAIN TEXT_{SP-EC}*(E_{EC-PK}*RN_{SP-EC}*RN_{EC}*Skey_{EC}*STD_{SP-EC})]*DS_{SP-Private-Key}}*[TID_{SP-M}*PLAIN TEXT_{SP-M}*E_{M-PK}(RN_{SP-M}*RN_M*Skey_M*STD_{SP-M})]>>DS_{SP-Private-Key} is sent back to the merchant through a network. Figure 8 depicts the final format and content of the combined KE response message from the SP to the merchant.

5 When the merchant receives the KE response message 232, the merchant first separates the DS_{SP-Private-Key}, which was signed by the SP, and then feeds the data portion of the combined KE response message into a one-way hash algorithm to recalculate the message digest MD[^]_{SP-M}. The merchant then separates the data portion of the SP's KE response message, i.e., TID_{SP-M}, PLAIN TEXT_{SP-M}, CRYPTO_{SP-M}, [(TID_{SP-EC}*PLAIN TEXT_{SP-EC}*CRYPTO_{SP-EC})]*DS_{SP-Private-Key}. The merchant uses SP's public key (selected from 144) to decrypt the digital signature DS_{SP-Private-Key} to recover the message digest MD_{SP-M}. The merchant compares 234 the newly hashed MD[^]_{SP-M} with the MD_{EC}. If there is any discrepancy between MD[^]_{SP-M} and MD_{SP-M}, the KE response message has been corrupted and is therefore rejected 236. If MD[^]_{SP-M} and MD_{SP-M} match, then the merchant identifies the part of the response message which is meant for him and decrypts the cryptogram CRYPTO_{SP-M} 238 using his own private key. The merchant should be able to recover the original random number RN_M (of 148) that he sent to the SP in the KE request message. The merchant compares 240 the recovered random number RN_M (of the step 238) with the original random number RNM. If they are not equal, then the message has been corrupted and the message is rejected 242. Since the random number RN_M can only be recovered by the SP using the correct SP private key, it is assured that the sender of the message is indeed the selected SP. The merchant then forwards the EC's KE response message [(TID_{SP-EC}*PLAIN TEXT_{SP-EC}*CRYPTO_{SP-EC})]*DS_{SP-Private-Key} to the EC and prepares for the transaction phase of the transaction.

20 When the EC receives the KE response message 260, the EC first separates the DS_{SP-Private-Key}, which was signed by the SP, and then feeds the data portion of the KE response message for the EC into a one-way hash algorithm producing a MD[^]_{SP-EC}. The EC then separates the data portion of the message, i.e., TID_{SP-EC}, PLAIN TEXT_{SP-EC}, CRYPTO_{SP-EC}, DS_{SP-Private-key}. The EC uses SP's public key (selected in 120) to decrypt the digital signature DS_{SP-Private-key} message and recovers the message digest MD_{SP}. The EC compares 262 the newly hashed MD[^]_{SP-EC} (in 260) with the MD_{SP-EC} recovered by decrypting the DS_{SP-Private-key} from the KE response message for EC. If there is any discrepancy between MD[^]_{SP-EC} and MD_{SP-EC} found, the KE response message for the EC has been corrupted and is therefore rejected 264. If MD[^]_{SP-M} and MD_{SP-M} match, the EC identifies the part of the response message which is meant for him and decrypts 266 the cryptogram CRYPTO_{SP-EC}, which is contained in the message, using his own private key. The EC should be able to recover the original random number RN_{EC} (of 124) that was sent in the EC KE request message. The EC compares 268 the recovered random number RN_{EC} (of 266) with the original random number RN_{EC} (of 124). If the random numbers are not equal, then the message has been corrupted and the message is rejected 270. Since only the SP using the correct

1 SP private key can recover the random number RN_{EC} , this serves to ensure that the sender of the message is indeed the selected SP. The EC prepares for the transaction phase of the transaction.

5 There will be a predefined timeout period set in the EC and the merchant. During a transaction, if a response message is not received within a timeout period, the EC and the merchant will consider the transaction aborted and will either retry or start the recovery process.

10 After successful completion of the KE message exchanges, the SP has EC's public key and the merchant's public key. At this point, both the EC and the merchant has a random number, a transaction ID, and a session key from the SP. The EC and the merchant must send the two random numbers recovered from the KE response message back to the SP to complete the key exchange phase of the transaction. This can be done in two ways. The random numbers can be sent back through a confirmation message from both the EC and the merchant. Or the random numbers can be sent back as part of the next message going out from the EC and the merchant to the SP, such as a transaction message. The second method is simpler and is described in phase II below. The random numbers are used only once to ensure the correctness of the key exchange between the SP and merchant, and the SP and EC. Once the session keys and transaction identification number have been established, the random number are no longer be used.

PHASE II: TRANSACTION PHASE

20 During the transaction phase, the merchant and the EC each sends their own account information such as an account number and other transaction related data such as transaction amount, request for approval or other processing, to the SP. Again, the EC and the merchant talk to the SP individually but through combined messages and the merchant is responsible for combining the messages and sending them as one message to the SP.

25 The EC first forms the transaction message by concatenating the random number RN_{SP-EC} 274 from the SP and the EC's account information with the selected SP, AI_{EC} 276, transaction amount TA 280 and any other sensitive data 278 relevant to the transaction and/or required by the SP. The EC encrypts 272 them using the session key $Skey_{EC}$ assigned by the SP. The $Skey_{EC}$ is a secret key and uses a cryptographic algorithm different from the cryptographic algorithm used for the public key encryption. The resulting cryptogram $CRYPTO_{EC}$, i.e., $Skey_{EC}(RN_{SP-EC} * STD_{EC} * AI_{EC} * TA)$, is then combined 282 with the transaction ID TID_{SP-EC} 284 and the plain text PLAIN TEXT_{EC} 286, if any, to form the data portion of the EC's transaction message, $TID_{SP-EC} * PLAIN TEXT_{EC} * CRYPTO_{EC}$. The data portion 282 is fed into a one-way hash algorithm 288 to calculate the message digest MD_{EC} and the MD_{EC} is then digitally signed 290 by the EC's private key 292. The resulting digital signature 290 is combined with the data portion of the message (from 282) 294 to form EC's transaction request message and then sent to the merchant, $[TID_{SP-EC} * PLAIN TEXT_{EC} * Skey_{EC}(RN_{SP-EC} * STD_{EC} * AI_{EC} * TA)] * DS_{EC-Private-Key}$.

30 The merchant goes through essentially the same steps to form his transaction message. The merchant forms his transaction message by concatenating 246 the RN_{SP-M} from the SP and the

1 merchant's account information with the selected SP, AI_M 248, transaction amount TA 252 and
any other sensitive data STD_M 250 relevant to the transaction and/or required by the SP. The
merchant encrypts them 244 using the session key $Skey_M$ assigned by the SP. The session key
 $Skey_M$ is a secret key and is created using a different cryptographic algorithm, such as DES, from
5 the cryptographic algorithm used for public key encryption. The session key $Skey_M$ is used to
perform the encryption at this point to create the cryptogram $CRYPTO_M$. The resulting
cryptogram $CRYPTO_M$, i.e., $Skey_M(RN_{SP-M} * STD_M * AI_M * TA)$, is then combined 254 with the
transaction ID TID_{SP-M} 256 and the plain text $PLAIN TEXT_M$ 258, if any, to form the data portion
of the merchant's transaction message, $TID_{SP-M} * PLAIN TEXT_M * CRYPTO_M$. This data is
10 combined 296 with the EC's transaction request to form the data portion of the final transaction
request message for the SP, $[TID_{SP-EC} * PLAIN TEXT_{EC} * Skey_{EC}(RN_{SP-EC} * STD_{EC} * AI_{EC} * TA)] * DS_{EC-Private-Key} * [TID_{SP-M} * PLAIN TEXT_M * Skey_M(RN_{SP-M} * STD_M * AI_M * TA)]$. As before, the merchant feeds his combined data through a one-way hash algorithm 298 to
15 calculate the message digest MD_M and the MD_M is then digitally signed 300 by the merchant's
private key 302. The resulting digital signature $DS_{M-Private-Key}$ 300 is combined 304 with the data
portion of the message (from 296) to form the final transaction request message and is then sent
to the SP, $\{[TID_{SP-EC} * PLAIN TEXT_{EC} * Skey_{EC}(RN_{SP-EC} * STD_{EC} * AI_{EC} * TA)] * DS_{EC-Private-Key} * [TID_{SP-M} * PLAIN TEXT_M * Skey_M(RN_{SP-M} * STD_M * AI_M * TA)]\} * DS_{M-Private-Key}$. Figure 9 depicts the final
format of the transaction request message.

20 When the SP receives the transaction request message, the SP first checks 306 the two
transaction identification numbers, i.e., TID_{SP-EC} and TID_{SP-M} , sent by the EC and the merchant
and makes sure they are valid. When either TID_{SP-M} (of 210) or TID_{SP-EC} (of 186) is found invalid
306, then the message is rejected 308. If the transaction identification numbers are both valid,
then the SP proceeds to separate the $DS_{M-Private-Key}$ from the data portion of the message and feeds
25 the data portion of the message, $\{[TID_{SP-EC} * PLAIN TEXT_{EC} * Skey_{EC}(RN_{SP-EC} * STD_{EC} * AI_{EC} * TA)] * DS_{EC-Private-Key} * [TID_{SP-M} * PLAIN TEXT_M * Skey_M(RN_{SP-M} * STD_M * AI_M * TA)]\}$ into a one-way hash algorithm to calculate the message digest MD^M of
this message. The SP separates the data portion of the message, i.e., TID_{SP-M} , $PLAIN TEXT_M$, $CRYPTO_M$, $DS_{M-Private-Key}$, $(TID_{SP-EC} * PLAIN TEXT_{EC} * CRYPTO_{EC}) * DS_{EC-Private-Key}$. The
30 SP decrypts 310 the $DS_{M-Private-Key}$ using the merchant's public key and compares the newly
recovered message digest MD_M with the message digest just calculated MD^M (from 306). If MD^M and MD_M are not equal, the message has been corrupted and is rejected 314. If MD^M and MD_M match, then the SP decrypts 316 the encrypted portion of the message using the session
35 key $Skey_M$ (of 210) it assigned to the merchant during the KE phase and recovers the data fields
contained in the encrypted portion. The SP compares 318 the random number RN_{SP-M} the
merchant sends back in the message with the message the SP sent to the merchant originally,
 RN_{SP-M} (from 208). If the random numbers are not equal, then the merchant has failed the mutual
authentication test and the message is rejected 320.

In addition, the SP will verify the EC's account information AI_{EC} and the transaction data such as the transaction amount TA. The message is rejected 320 if the AI is no longer valid. It is also rejected when the TA from the EC and the TA from the merchant do not match. There may be other conditions for invalidating a message. If the account information AI_{EC} and the transaction are valid, then the SP goes on to verify the EC portion of the message.

As with the merchant's message, the SP first separates 322 the $DS_{EC-Private-Key}$ from the EC's message and feeds the data portion of the EC's message, $(TID_{SP-EC} * PLAIN\ TEXT_{EC} * CRYPTO_{EC})$ into a one-way hash algorithm to calculate the message digest MD^{\wedge}_{EC} of the EC message. The SP separates the data portion of EC's transaction request, TID_{SP-EC} , $PLAIN\ TEXT_{EC}$, $CRYPTO_{EC}$, $DS_{EC-Private-Key}$. The SP decrypts 324 $DS_{EC-Private-Key}$ using EC's public key PK_{EC} and recovers MD_{EC} . The SP compares 326 the recovered MD_{EC} with MD^{\wedge}_{EC} . If MD^{\wedge}_{EC} and MD_{EC} are not equal, the message has been corrupted and is rejected 328. If MD^{\wedge}_{EC} and MD_{EC} match, then the SP decrypts 330 the encrypted portion of the EC message using the session key $Skey_{EC}$ (of 186) it assigned to the EC during the KE phase and recovers the data fields contained in it. The SP compares 332 the random number RN_{SP-EC} the EC sends back in the message with the random number RN_{SP-EC} it sent out to the EC originally (in 184). If the random numbers are not equal, then the EC has failed the mutual authentication test and the message is rejected 334. The SP will verify the merchant's account information AI_M and the transaction data such as the transaction amount TA and will reject the message when the account information is invalid or when the transaction data does not meet the SP's criterion 334. Once the integrity and authenticity of the overall message has been established, the SP can process the data contained in the message and send a response message back. The random number that is sent back in this message completes the mutual authentication between the SP and the merchant, and between the SP and the EC. After this message, no exchange of random numbers will be necessary. The SP can chooses to use the random number as the transaction identification number which the merchant and the EC will use in all subsequent messages that they send to the SP.

As before, the response message contains information for both the EC and the merchant. To format the transaction response message for the EC, the SP generates the response data for the EC, $Response\ Data_{SP-EC}$ 338, and encrypts 336 it using the session key $Skey_{EC}$ assigned to the EC. Only sensitive data is encrypted. Non-sensitive response data is included in the plain text. The cryptogram $CRYPTO_{SP-EC}$, i.e., $E_{Skey-EC}(Response\ Data_{SP-EC})$, is combined 340 with the transaction identification number TID_{SP-EC} 342 that the SP assigned to the EC (from 194) and the plain text that the SP has for EC 344, if any, to form the data portion of the response message for the EC, i.e., $TID_{SP-EC} * PLAIN\ TEXT_{SP-EC} * E_{Skey-EC}(Response\ Data_{SP-EC})$. The data portion of the message is fed into a hash algorithm 346 to generate a MD_{SP-EC} which is digitally signed 348 by the SP using the SP's private key 350. The $DS_{SP-Private-Key}$ is combined 352 with the data portion of the response message (from 340) to form the complete response message for the EC, $[TID_{SP-EC} * PLAIN\ TEXT_{SP-EC} * E_{Skey-EC}(Response\ Data_{SP-EC})] * DS_{SP-Private-Key}$.

1 To format the transaction response message for the merchant, the SP generates the response
 data for the merchant, Response Data_{SP-M} 356, and encrypts 354 it using the session key Skey_M
 assigned to the merchant (from 210). The cryptogram CRYPTO_{SP-M}, is combined 358 with the
 5 transaction identification number TID_{SP-M} assigned to merchant 360 (from 218) and the plain text
 PLAIN TEXT_{SP-M} that the SP has for merchant 362, if any, to form the data portion of the
 response message for the merchant, TID_{SP-M}*PLAIN TEXT_{SP-M}*CRYPTO_{SP-M}. The data is then
 combined 364 with the completed response message for the EC to form the data portion of the
 response message for both the EC and the merchant, [(TID_{SP-EC}*PLAIN TEXT_{SP-EC}*E_{Skey-EC}(Response Data_{SP-EC})]*DS_{SP-Private-Key}*[TID_{SP-M}*PLAIN TEXT_{SP-M}*E_{Skey-M}(Response Data_{SP-M})].
 10

The data is then fed into a hash algorithm 366 to generate a MD_{SP-M} which is digitally signed
 368 by the SP using the SP's private key 370. The DS_{SP-Private-Key} is combined 372 with the data
 portion of the response message for both the EC and the merchant to form the complete response
 15 message for both the EC and the merchant, <<{[TID_{SP-EC}*PLAIN TEXT_{SP-EC}*E_{Skey-EC}(Response Data_{SP-EC})]*DS_{SP-Private-Key}}*[TID_{SP-M}*PLAIN TEXT_{SP-M}*E_{Skey-M}(Response Data_{SP-M})]>> DS_{SP-Private-Key}. The SP then sends its response message back to the merchant. Figure 10 depicts the final
 format of the transaction response message.

When the merchant receives the message, the merchant first checks 374 the transaction
 identification number, TID_{SP-M}, in the message and makes sure it is valid. If the transaction
 20 identification number is invalid then the message is rejected 376. If the TID_{SP-M} is valid, then
 the merchant separates the DS_{SP-Private-Key} which was signed by the SP from the data portion of the
 message, and then feeds the data portion of the transaction response message <<{[TID_{SP-EC}*PLAIN TEXT_{SP-EC}*E_{Skey-EC}(Response Data_{SP-EC})]*DS_{SP-Private-Key}}*[TID_{SP-M}*PLAIN TEXT_{SP-M}*E_{Skey-M}(Response Data_{SP-M})>> into a one-way hash algorithm producing a MD_{SP-M}. The
 25 merchant separates the data portion of the message into different parts, TID_{SP-M}, PLAIN
 TEXT_{SP-M}, CRYPTO_{SP-M}, DS_{SP-Private-Key} (TID_{SP-EC}*PLAIN TEXT_{SP-EC}*CRYPTO_{SP-EC}*DS_{SP-Private-Key}) and prepares to forward SP's transaction response message to the EC. The merchant
 deciphers 378 the encrypted portion of the SP's message using the session key Skey_M assigned
 30 by the SP during the KE phase and recovers the data fields contained within it. The merchant
 then uses SP's public key, PK_{SP} (from 144), to decipher the digital signature DS_{SP-Private-Key} to
 recover MD_{SP-M}. The merchant compares 380 the newly hashed MD[^]_{SP-M} (from 374) with the
 recovered MD_{SP-M}. If MD[^]_{SP-M} and MD_{SP-M} do not match, then the transaction response message
 has been corrupted and is therefore rejected 382. If the message digests match, then the
 35 merchant starts processing the message. As usual, the EC portion of the transaction response
 message (TID_{SP-EC}*PLAIN TEXT_{SP-EC}*CRYPTO_{SP-EC}*DS_{SP-Private-Key}) is passed to EC.

When the EC receives the transaction response message, the EC first checks 394 the
 transaction identification number, TID_{SP-EC}, in the message and makes sure it is valid. If the
 transaction identification numbers is invalid, then the message is rejected 396. If the transaction

1 identification number is valid, then the merchant separates the $DS_{SP\text{-}Private\text{-}Key}$ which was signed
by the SP, from the data portion of the transaction response message, and then feeds the data
portion of the EC transaction response message $TID_{SP\text{-}EC} * PLAIN\ TEXT_{SP\text{-}EC} * E_{Skey\text{-}EC}$ (Response
Data_{SP-EC}) into a one-way hash algorithm producing $MD^{\wedge}_{SP\text{-}EC}$. The EC separates the message
5 into different parts, $TID_{SP\text{-}EC}$, $PLAIN_{SP\text{-}EC}$, $CRYPTO_{SP\text{-}EC}$, $DS_{SP\text{-}Private\text{-}Key}$. The EC decrypts 398
the encrypted portion of SP's message using the session key Skey assigned by the SP during the
KE phase and recovers the data fields contained within it. The EC uses SP's public key (from
10 120) to decrypt the digital signature $DS_{SP\text{-}Private\text{-}Key}$ and recovers the message digest $MD_{SP\text{-}EC}$. The
merchant compares 400 the newly hashed $MD^{\wedge}_{SP\text{-}EC}$ 394 with the recovered $MD_{SP\text{-}EC}$. If $MD^{\wedge}_{SP\text{-}EC}$
and $MD_{SP\text{-}EC}$ do not match, then the transaction response message has been corrupted and is
therefore rejected 402. If the message digests match, then the EC starts processing the message.

15 At the end of the transaction, the EC and the merchant can, if required by the SP, send an acknowledgement message to the SP to signal that the response message has been correctly received and processed. This acknowledgement data can be included as a part of the next message to be sent to the SP, if there are more messages to be exchanged between the SP and the merchant and the EC before the transaction ends. Or the acknowledgement data can be a message by itself.

20 To format the acknowledgement message, the EC first encrypts 404 the sensitive part of the acknowledgement data, Acknowledgement Data_{EC}, 406, if any, using the session key, Skey_{EC}, thus creating Skey_{EC}(Acknowledgement Data_{EC}). The EC combines 408 the resulting cryptogram with the transaction identification number TID_{SP-EC} 410 assigned by the SP and the plain text PLAIN TEXT_{EC} 412, if any. This forms the data portion of EC's acknowledgement message, $TID_{SP\text{-}EC} * PLAIN\ TEXT_{EC} * Skey_{EC}$ (Acknowledgement Data_{EC}). This combined data is then fed 25 into a one-way hash algorithm 414 to generate the MD_{EC}. The resulting MD_{EC} is then digitally signed 416 by the EC using the EC's private key 418 to generate a $DS_{EC\text{-}Private\text{-}Key}$. The DS_{EC-Private-Key} is combined 420 with the data portion of the message (from 408) to form the complete acknowledgement message for the EC; $[TID_{SP\text{-}EC} * PLAIN\ TEXT_{EC} * Skey_{EC}] * DS_{EC\text{-}Private\text{-}Key}$. The acknowledgement message is then sent to the merchant.

30 The merchant goes through the same steps to form his own acknowledgement message. To format the acknowledgement message, the merchant first encrypts the sensitive parts of the acknowledgement data, Acknowledgement Data_M 386, if any using the session key Skey_M assigned by the SP to merchant, thus creating Skey_M(RN_{SP-M}*Acknowledgement Data_M). The merchant combines 388 the resulting cryptogram with the transaction identification number TID_{SP-M} 390 assigned by the SP, and the plain text PLAIN TEXT_M (from 392), if any. This forms 35 the data portion of the merchant's acknowledgement message, $TID_{SP\text{-}M} * PLAIN\ TEXT_M * Skey_M$ (RN_{SP-M}*Acknowledgement Data_M). This data portion is further combined 422 with the acknowledgement message received from the EC to form the data portion of the combined acknowledgement message for the SP, {[TID_{SP-EC} * PLAIN TEXT_{EC} * Skey_{EC}] * DS_{EC-Private-Key}}.

1 $\text{Data}_{\text{EC}}] * \text{DS}_{\text{EC-Private-Key}} \} * [\text{TID}_{\text{SP-M}} * \text{PLAIN TEXT}_M * \text{Skey}_M(\text{Acknowledgement Data}_M)]$. The merchant feeds the data portion of the combined acknowledgement message for the SP into a one-way hash algorithm to generate the message digest MD_M . The resulting MD_M is then 5 digitally signed by the merchant using the merchant's private key 428 to generate $\text{DS}_{\text{M-Private-Key}}$ 426. The $\text{DS}_{\text{M-Private-Key}}$ is combined 430 with the data portion of the message (from 422) to form the final combined acknowledgement message of the EC and the merchant designated for the SP, $<<\{\text{TID}_{\text{SP-EC}} * \text{PLAIN TEXT}_{\text{EC}} * \text{Skey}_{\text{EC}}(\text{Acknowledgement Data}_{\text{EC}})\} * \text{DS}_{\text{EC-Private-Key}}\} * [\text{TID}_{\text{SP-M}} * \text{PLAIN TEXT}_M * \text{Skey}_M(\text{Acknowledgement Data}_M)]>> * \text{DS}_{\text{M-Private-Key}}$. This message is then sent to the SP. Figure 11 depicts the final format of the transaction acknowledgement message.

10 $\text{TID}_{\text{SP-M}}$ is the transaction identification number assigned by the SP to the merchant (from 218) and $\text{TID}_{\text{SP-EC}}$ is the transaction identification number assigned by the SP to the EC (from 194). Upon receiving the transaction acknowledgement message, the SP checks 432 the two transaction identification numbers, $\text{TID}_{\text{SP-M}}$ and $\text{TID}_{\text{SP-EC}}$, sent by the EC and the merchant and makes sure they are valid. When either $\text{TID}_{\text{SP-M}}$ or $\text{TID}_{\text{SP-EC}}$ is found invalid, then the message 15 is rejected 434. If the transaction identification numbers are both valid, then the SP proceeds to separate the $\text{DS}_{\text{M-Private-Key}}$ from the combined acknowledgement message and feeds the data portion of the combined acknowledgement message $<<\{\text{TID}_{\text{SP-EC}} * \text{PLAIN TEXT}_{\text{EC}} * \text{Skey}_{\text{EC}}(\text{Acknowledgement Data}_{\text{EC}})\} * \text{DS}_{\text{EC-Private-Key}}\} * [\text{TID}_{\text{SP-M}} * \text{PLAIN TEXT}_M * \text{Skey}_M(\text{Acknowledgement Data}_M)]>>$ into a one-way hash algorithm to calculate the 20 message digest MD_M^* of this message. The SP separates the data portion of the message, $\text{TID}_{\text{SP-M}}$, PLAIN TEXT_M , CRYPTO_M , $\text{DS}_{\text{M-Private-Key}}$, $(\text{TID}_{\text{SP-EC}} * \text{PLAIN TEXT}_{\text{EC}} * \text{CRYPTO}_{\text{EC}}) * \text{DS}_{\text{EC-Private-Key}}$. The SP decrypts 436 the $\text{DS}_{\text{M-Private-Key}}$ using the merchant's public key PK_M and compares the recovered message digest MD_M 432 with the message digest just calculated MD_M^* 436. If MD_M^* and MD_M are not equal, then the message has been corrupted and is rejected 440. 25 If MD_M^* and MD_M match, then the SP decrypts 442 the encrypted portion of the merchant's acknowledgement message using the session key Skey_M (from 210) that it assigned to the merchant during the KE phase and recovers the acknowledgement data contained within it.

30 The SP separates 444 the $\text{DS}_{\text{EC-Private-Key}}$ from the EC's acknowledgement message and feeds the data portion of the EC's acknowledgement message, $\text{TID}_{\text{SP-EC}} * \text{PLAIN TEXT}_{\text{EC}} * \text{CRYPTO}_{\text{EC}}$, into a one-way hash algorithm to calculate the message digest MD_{EC}^* of this message. The SP separates the data portion of the EC's acknowledgement message, $\text{TID}_{\text{SP-EC}}$, $\text{PLAIN TEXT}_{\text{EC}}$, $\text{CRYPTO}_{\text{EC}}$, $\text{DS}_{\text{EC-Private-Key}}$. The SP decrypts 446 the $\text{DS}_{\text{EC-Private-Key}}$ using the EC's public key PK_{EC} and compares 448 the recovered MD_{EC} with the message digest just calculated MD_{EC}^* 444. If the message digests are not equal, then the message has been corrupted and is rejected 450. 35 If MD_{EC}^* and MD_{EC} match, then the SP decrypts 452 the encrypted portion of the message using the session key Skey_{EC} (from 186) that it assigned to the EC during the KE phase and recovers the acknowledgement data contained within it. This completes the processing of the transaction phase of the transaction 454.

1 Throughout the transaction, in a preferred embodiment, the EC works with interface
software provided by Internet browser software such as the Microsoft Explorer or Netscape
Navigator. In a typical session, the cardholder points his browser to the merchant's URL and
orders goods or services from the merchant. At the time of payment, the browser will invoke the
5 EC interface software, which can be built into the browser or included as a plug-in or add-on
software component, and allow the transaction to proceed. The cardholder can point his browser
to the URL of any SP member.

10 The two-phased transaction described in figure 6A-6Q above is just a specific case of
applying the two-phased key-exchange-transaction model. In the two-phased transaction
described in figures 6A-6Q, the number of parties involved in the transaction is three: the EC,
15 the merchant and the SP. The two-phased key-exchange-transaction model is similarly
applicable to cases where the number of parties involved varies from two to many. In a
transaction that involves more than three parties, there is only one party that plays the role of the
SP. All other parties use the public key of the selected SP to perform the initial key exchange
and use session keys and transaction Ids assigned by the SP to carry out the transaction.

20 The two-phased key-exchange-transaction model is applicable to organization schemes
wherein: (1) the participants can be arranged with possible routers in series with the service
provider; or (2) the participants can be arranged with possible routers in a hierarchical
organization. These additional organization schemes may involve routers, which route messages
25 to the next level. A level of a hierarchy may be composed of any number of participants and/or
routers. The next level is the next participant or router that is next in the sequence or hierarchy.
In a hierarchical organization scheme, the next level includes all possible next participants and
routers. For the hierarchical organization scheme, the SP establishes the criterion for
determining the next participant or router to which a message is sent.

30 A router is a gateway/conduit, which collects the messages from a previous level and
performs some processing on the messages according to an SP's requirements such as combining
them, and then forwards the messages to the SP. Each participant need only form his own
message (data and digital signature) and send it to the next level. A participant combines all the
messages he receives with his own message and digitally signs the combined message before
35 sending it to next level. In the hierarchical organization's simplest form, there is only one
message router, which collects messages from all the other participants and sends the combined
message to the SP.

35 In the series organization, an originator of a transaction is in series with routers and/or
participants who in turn are in series with a service a service provider 60. In the preferred
embodiment of the invention, each element shown in figure 12 is a participant. In an alternative
embodiment of the invention, any intermediate element between the originator and the SP can
be a router.

An originator conducts a transaction with participants 1100, 1120, 1140 and 1160 and a

1 service provider that have been arranged in series as shown in Figure 12. This is similar to the
three-party scenario described in figures 6A-6Q except for the fact that now there is more parties
involved. Note participants 3,4,5,6 ... n-2 that have been arranged in series 1180. Each of the
5 participants prepares his own message, incorporates it with the message he receives from a prior
participant, if any, appends a digital signature with the message, and then sends it to the next
participant in the line. The combined message is eventually sent to the SP and the SP forms the
response message accordingly and sends it back through the same path the original request
message has traveled.

10 Figure 13 shows elements arranged in a hierarchical organization scheme, where each
element, $X_{1,1}$ to $X_{1,n}$ ($n = 1, 2, 3, \dots$) 1200, is a participant of the transaction and not a message
router, and each element, $X_{j,k}$ ($j = 2, 3, 4, \dots; k = 1, 2, 3, \dots m$; m is a variable of type n ; m may
be a different value for different levels of a hierarchy) 1210, can either be a participant or a
router. The upward pointing bold arrow represents sending a request message 1220. The
downward pointing arrow represents sending a response message 1230.

15 Each participant collects messages from a number of participants he is responsible for and,
after combining the messages with his own and forming a new message, sends the new message
to the next level. A hierarchical organization scheme may include only one participant to as
many as is required (The most regressive case of the hierarchical scheme is one participant and
20 one service provider). Eventually, at the last element before the service provider, $X_{\sigma,1}$ where σ
is of type n , all messages are combined into one message 1240, which is then sent to the SP 60.
Again, the SP forms the response message and sends it back through the same route.

25 In the case when the SP is not directing the transaction, the members are conducting the
transaction among themselves using the session key generated by the SP. A transaction can
occur between two or more members. When there are more than two members involved in the
transaction, the messages can flow from member to member in any order. A member sends a
transaction request message and receives a transaction response message. A member does not
necessarily have to receive a transaction response message from the same member that he sent
the transaction request message. For example, three members in a transaction can be organized
30 in a ring and send messages around the ring. A first member can send a transaction request
message to a second member who in turn sends a transaction request message and a transaction
response message to third member. The third member sends a transaction request message and
a transaction response message to the first member, and the first member sends a transaction
response message to a second member. A member receiving a transaction request message
creates a transaction response message, which eventually will be sent to the member who sent
35 the transaction request message.

During the key exchange phase, the SP obtains the public keys of all the transaction
participating members. The SP sends to each participating member, the other members' public
keys prior to the participating members conducting a transaction among them. The transaction

1 request messages and the transaction response message include plain text, if any, a cryptogram,
and a digital signature of the sending party.

5 In the case when the SP needs to act as the surrogate-certificate for the EC and/or the merchant in order to deal with a certificate-based external system, the SP shields the EC and/or the merchant from the operation of the external interface. The SP only returns to the EC and/or the merchant, the information needed to complete the transaction with the EC and/or the merchant.

10 While there have been described herein what are considered to be preferred and exemplary embodiments of the present invention, other modifications of the invention shall be apparent to those with ordinary skill in the art. Therefore, it is desired to be secured in the appended claims all such modifications and extensions as fall within the true spirit and scope of the invention. The invention is to be construed as including all embodiments thereof that fall within the scope of the appended claims and the invention should only be limited by the appended claims below. In addition, one with ordinary skill in the art will readily appreciate that other applications may be substituted for those set forth herein without departing from the spirit and scope of the present invention.

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1 CLAIMS:

1. A system for electronic transactions comprising:
 - an electronic card having,
 - a cryptographic service for encryption and decryption,
 - a data area for storing information, and
 - a data area for storing cardholder with the service provider member terminal;
 - a service provider member terminal responsive to the electronic card; and
 - a service provider terminal in communication service provider information.
- 10 2. The system of claim 1 wherein the electronic card is a physical card.
3. The system of claim 1 further comprising software having the electronic card.
- 15 4. The system of claim 1 wherein the electronic card further comprises a card operating system for loading and updating cardholder information, changing a PIN, and managing the service provider data area.
5. The system of claim 1 wherein the electronic card performs external communication read/write operations, and communication protocol handling.
- 20 6. The system of claim 1 wherein the electronic card further comprises software to manage the electronic card.
- 25 7. The system of claim 1 wherein the data area for storing service provider information comprises a service provider record comprising:
 - a name field indicating the service provider;
 - a key value; and
 - an account information field containing information unique to each service provider.
- 30 8. The system of claim 1 wherein the electronic card further comprises application software.
9. The system of claim 1 wherein the electronic card further comprises applets.
- 35 10. The system of claim 1 further comprising an external system wherein the service provider terminal communicates with the external system.
11. The system of claim 7 wherein each service provider record further comprises a card type field specifying the type of instrument a service provider supports.

1 12. A method of conducting an electronic transaction using an electronic card comprising the steps of:

generating a session key at the service provider;

5 exchanging keys by sending a key from a member to a service provider and sending a session key from the service provider to the member; and

using the session key to conduct a transaction.

13. The method of claim 12 wherein the step of exchanging keys comprises the steps of:

sending a key exchange request message from a member to a service provider; and

10 formatting a key exchange response including the session key for a member and sending the key exchange response to a member.

14. The method of claim 12 wherein the step of using a session key to conduct a transaction comprises the steps of:

15 formatting a member transaction request message using the session key and sending it to the service provider; and

formatting at the service provider, a transaction response message for the member and sending the transaction response message to the member.

20 15. The method of claim 12 wherein the step of using a session key to conduct a transaction comprises the steps of:

formatting by a first member, using the session key, a transaction request message, the transaction request message including a digital signature of the first member, and sending the transaction request message to a second member; and

25 formatting by a second member, using the session key, a transaction response message, the transaction response message including a digital signature of the second member, and sending the transaction response message to the first member.

30 16. The method of claim 12 wherein the step of using a session key to conduct a transaction comprises the steps of:

formatting by a first member, using the session key, a transaction request message, the transaction request message including a digital signature of the first member, and sending the transaction request message to an intermediate member; and

35 formatting by an intermediate member, using the session key, a transaction response message, the transaction response message including a digital signature of the intermediate member, and sending the transaction response message to a final member;

formatting by a final member, using the session key, a transaction response message, the transaction response message including a digital signature of the final member, and sending the

1 transaction response message to the first member.

17. The method of claim 12 wherein the step of exchanging keys comprises the steps of:
sending a key exchange request message from the electronic card to a merchant terminal;
5 combining at the merchant terminal, a merchant key exchange request message with the
electronic card's key exchange request message and sending the combined key exchange request
message to a service provider;

10 formatting a key exchange response including the session key for the merchant terminal,
formatting a key exchange response including the session key for the electronic card, combining
the key exchange responses into a combined key exchange response and sending the combined
key exchange response to the merchant terminal; and

15 separating at the merchant terminal, the key exchange response for the merchant from the key
exchange response for the electronic card system, and forwarding the key exchange response for
the electronic card to the electronic card.

18. The method of claim 12 wherein the step of using a session key to conduct a transaction
comprises the steps of:

20 formatting the electronic card's transaction request message using the session key and
sending it to the merchant terminal;

25 formatting at the merchant's terminal, using the session key, the merchant transaction request
message combining the received transaction request message with the merchant transaction
request message and sending the combined transaction request message to the service provider;

formatting by the service provider, using the session key, a transaction response message for
the merchant, a transaction response message for the electronic card system, and combining the
transaction response messages into a combined transaction response message and sending the
combined transaction response message to the merchant terminal; and

30 separating at the merchant terminal, the transaction response message for the merchant from
the transaction response message for the electronic card, and forwarding the transaction response
message for the electronic card system to the electronic card.

19. The method of claim 12 wherein when the service provider is directing the transaction,
only the service provider can read sensitive transaction data within a message sent from a
member.

35 20. The method of claim 12 wherein when the service provider is not directing the
transaction, only the service provider can read sensitive transaction data within a message sent
from a member during the key exchange phase.

- 1 21. The method of claim 13 wherein the key exchange response further comprises public
keys for every member involved in a transaction.
- 5 22. The method of claim 13 wherein a key exchange request message includes a member
generated random number within the encrypted part of the key exchange message.
- 10 23. The method of claim 13 wherein a key exchange request message includes a member
generated digital signature.
- 15 24. The method of claim 13 wherein a key exchange request message from a member
includes a cryptogram comprising:
 a random number of the member; and
 sensitive data of the member.
- 20 25. The method of claim 14 wherein a transaction message includes a random number within
the encrypted part of the transaction message.
- 25 26. The method of claim 14 wherein a transaction message includes a digital signature of a
sending party.
- 30 27. The method of claim 14 wherein only the service provider can read sensitive transaction
data within a transaction message.
- 35 28. The method of claim 14 further comprising the steps of:
 formatting at the member, using the session key, a transaction Acknowledgement message
and sending the transaction Acknowledgement message to the service provider.
29. The method of claim 18 further comprising the steps of:
 formatting at the electronic card, using the session key, a transaction Acknowledgement
message and sending the transaction Acknowledgement message to the merchant; and
 formatting at the merchant's terminal, using the session key, the merchant transaction
Acknowledgement message, combining the received transaction Acknowledgement message
with the merchant transaction Acknowledgement message and sending the combined transaction
Acknowledgement message to the service provider.
30. The method of claim 24 wherein the key exchange request message further comprises
plain text.

1 31. The method of claim 24 wherein the key exchange request message further includes a digital signature of a member.

5 32. The method of claim 24 wherein the cryptogram further comprises a public key of the member.

10 33. The method of claim 25 wherein a transaction message includes a digital signature of a sending party.

15 34. A method of sending a key exchange message comprising the steps of:
 satisfying electronic card access conditions by an electronic cardholder;
 selecting a service provider by the electronic cardholder;
 generating an electronic card random number by the electronic card;
 encrypting by the electronic card with a service provider's public key, a random number, an
 electronic card public key, and electronic card sensitive transaction data to form an electronic
 card cryptogram;
 combining by the electronic card the electronic card cryptogram with plain text, if any, to
 form an electronic card combination message;
 applying a hashing algorithm to the electronic card combination message to form an electronic
 card message digest;
 digitally signing by the electronic card, the electronic card message digest using the
 electronic card private key to form an electronic card digitally signed message;
 combining by the electronic card, the electronic card combination message with the
 electronic card digitally signed message to form a key exchange message from the electronic
 card; and
 sending the electronic card key exchange message from the electronic card to a merchant
 through a network.

20 35. The method of claim 34 further comprising the steps of:
 generating a merchant random number by a merchant device;
 encrypting by the merchant device with a service provider's (SP's) public key, a merchant
 random number, a merchant public key, and merchant sensitive data to form a merchant
 cryptogram;
 combining by the merchant device, the merchant cryptogram with plain text, if any, to form
 a merchant combination message;
 combining by the merchant device the electronic card (EC) key exchange message with the
 merchant combination message to form an EC-merchant combination message;
 applying a hashing algorithm to the EC-merchant combination message to form a merchant

1 message digest;
digitally signing by the merchant device, the merchant message digest using the merchant's
private key to form a merchant digitally signed message;
5 combining by the merchant, the EC-merchant combination message with the merchant
digitally signed message to form a merchant key exchange request message from the merchant;
and
sending the merchant key exchange request message from the merchant to a service provider
through a network.

10 36. A key exchange request message comprising:
electronic card plain text;
electronic card cryptogram, encrypted with a service provider public key, comprising an
electronic card random number, an electronic card public key, and electronic card sensitive
transaction data;
15 an electronic card digital signature of the electronic card plain text and the electronic card
cryptogram;
merchant plain text;
merchant cryptogram, encrypted with the service provider public key, of a merchant random
number, a merchant public key, and merchant sensitive transaction data; and
20 a merchant digital signature of the merchant plain text and the merchant cryptogram.

37. A key exchange response message comprising:
service provider (SP) plain text for the electronic card (EC);
SP transaction identification number for the EC;
25 SP cryptogram for the EC, encrypted with the EC public key, of the EC random number, an
SP random number for the EC, a session key, and SP sensitive transaction data for the EC;
an SP digital signature of the SP plain text for the EC, the SP transaction identification
number for the EC; and the SP cryptogram for the EC;
SP plain text for the merchant;
30 SP transaction identification number for the merchant;
SP cryptogram for the merchant encrypted with the merchant public key, of the merchant
random number, an SP random number for the merchant, a session key, and SP sensitive
transaction data for the merchant; and
35 an SP digital signature of the SP plain text for the merchant, the SP transaction identification
number for the merchant; and the SP cryptogram for the merchant.

38. A method of conducting an electronic transaction among multiple parties arranged in
series comprising the steps of:

- 1 sending a key exchange request message from an electronic card to a first party where the
first party is a message router or participant;
- 5 sending the key exchange request message from the first party to a next party if the first party
is a router;
- 5 combining a first party's key exchange request message with the electronic card's key exchange
request message and sending the combined key exchange request message to a next party if the
first party is a participant;
- 10 sending the key exchange request message to a next party if the current party is a message
router;
- 10 combining a current party's key exchange request message with a last party's key exchange
request message and sending the combined key exchange request message to a next party, if the
current party is a participant;
- 15 formatting, by the service provider, into one message, a key exchange response for each
participant and sending the message in reverse order of the path for sending the key exchange
request message to the service provider; and
- 15 separating, by every participant, the key exchange response for itself from the key exchange
responses for the other participants, and forwarding the remaining key exchange responses to the
other participants in reverse order of the path for sending the key exchange request message to
the service provider, until the electronic card receives its key exchange response.
- 20 39. A method of conducting an electronic transaction among multiple parties arranged in
series comprising the steps of:
- 20 sending a transaction request message from an electronic card to a first party where the first
party is a message router or participant;
- 25 sending the transaction request message from the first party to a next party if the first party
is a router;
- 25 combining a first party's transaction request message with the electronic card's transaction
request message and sending the combined transaction request message to a next party if the first
party is a participant;
- 30 sending the transaction request message to a next party if the current party is a message
router;
- 30 combining a current party's transaction request message with a last party's transaction
request message and sending the combined transaction request message to a next party, if the
current party is a participant;
- 35 formatting, by the service provider, into one message, a transaction response for each
participant and sending the message in reverse order of the path for sending the transaction
request message to the service provider; and
- 35 separating, by every participant, the transaction response for itself from the transaction

1 responses for the other participants, and forwarding the remaining transaction responses to the other participants in reverse order of the path for sending the transaction request message to the service provider, until the electronic card receives its transaction response.

5 40. A method of conducting an electronic transaction among multiple parties arranged in a hierarchical organization comprising the steps of:

sending a key exchange request message from an electronic card to a first party where the first party is a message router or participant;

10 sending the key exchange request message to a next party $X_{j,k}$ ($j = 2, 3, 4, \dots; k = 1, 2, 3, \dots, m$; m is a variable of type n ; $n = 1, 2, 3, \dots$; m can be different values for different values of j) if the first party is a message router;

15 combining a first party's key exchange request message with the electronic card's key exchange request message and sending the combined key exchange request message to a next party $X_{j,k}$ if the first party is a participant;

sending the key exchange request message to the next party $X_{j,k}$ if a current party $X_{j,k}$ is a message router;

20 combining a current party $X_{j,k}$'s key exchange request message with the last party's key exchange request message and sending the combined key exchange request message to the next party $X_{j,k}$, if the current party $X_{j,k}$ is a participant;

25 formatting, by the service provider, into one message, a key exchange response for each participant and sending the message in reverse order of the path for sending the key exchange request message to the service provider; and

separating, by every participant, the key exchange response for itself from the key exchange responses for the other participants, and forwarding the remaining key exchange responses to the other participants in reverse order of the path for sending the key exchange request message to the service provider, until the electronic card receives its key exchange response.

30 41. A method of conducting an electronic transaction among multiple parties arranged in a hierarchical organization comprising the steps of:

sending a transaction request message from an electronic card to a first party where the first party is a message router or participant;

35 sending the transaction request message to a next party $X_{j,k}$ ($j = 2, 3, 4, \dots; k = 1, 2, 3, \dots, m$; m is a variable of type n ; $n = 1, 2, 3, \dots$; m can be different values for different values of j) if the first party is a message router;

combining a first party's transaction request message with the electronic card's transaction request message and sending the combined transaction request message to a next party $X_{j,k}$ if the first party is a participant;

40 sending the transaction request message to the next party $X_{j,k}$ if a current party $X_{j,k}$ is a message router;

- 1 message router;
- 2 combining a current party $X_{j,k}$'s transaction request message with the last party's transaction
- 3 request message and sending the combined transaction request message to the next party $X_{j,k}$, if
- 4 the current party $X_{j,k}$ is a participant;
- 5 formatting, by the service provider, into one message, a transaction response for each
- 6 participant and sending the message in reverse order of the path for sending the transaction
- 7 request message to the service provider; and
- 8 separating, by every participant, the transaction response for itself from the transaction
- 9 responses for the other participants, and forwarding the remaining transaction responses to the
- 10 other participants in reverse order of the path for sending the transaction request message to the
- 11 service provider, until the electronic card receives its transaction response.

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FIG. 1

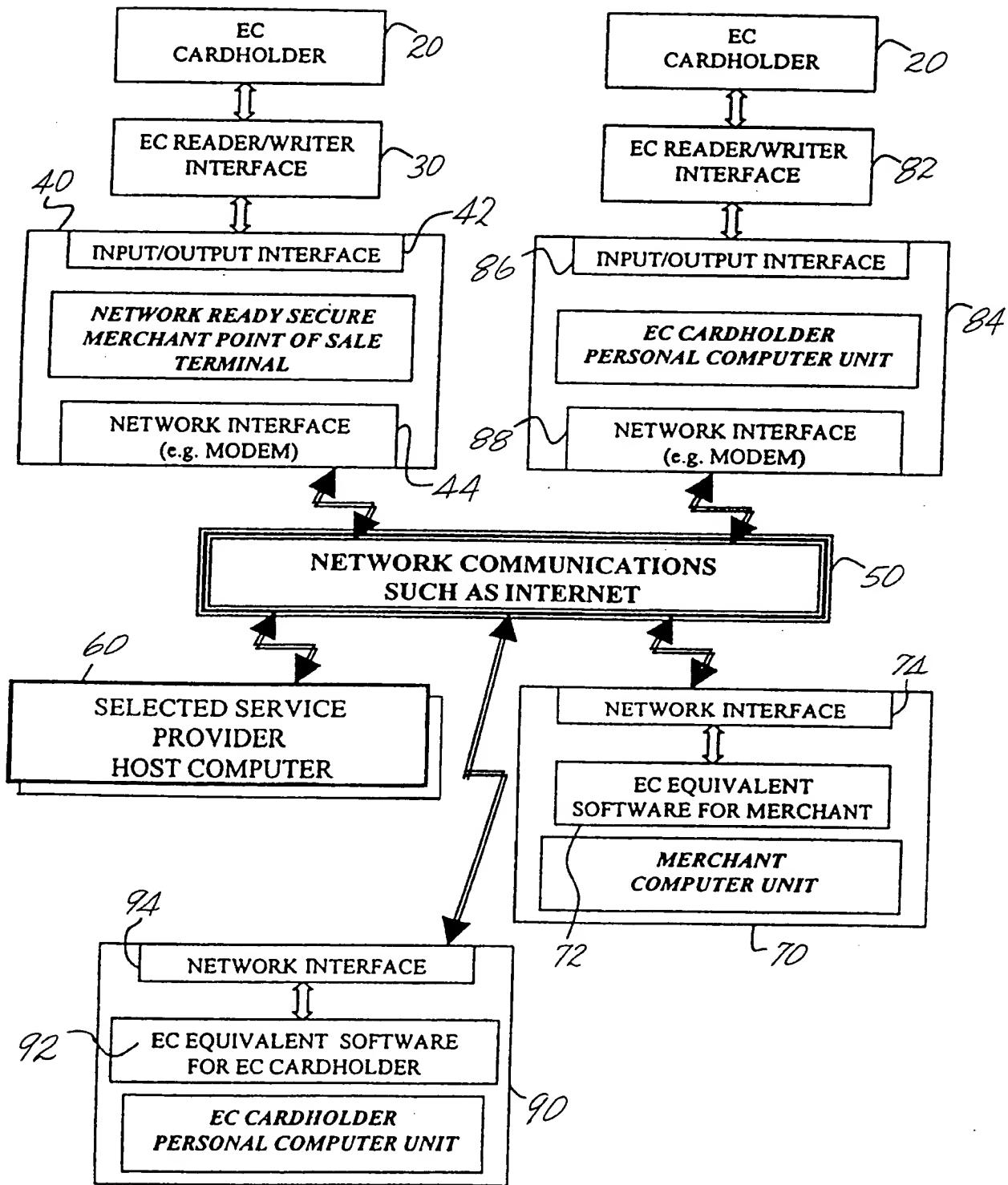


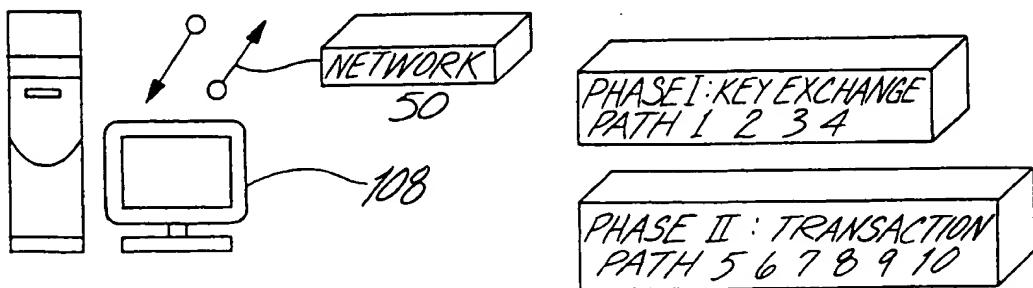
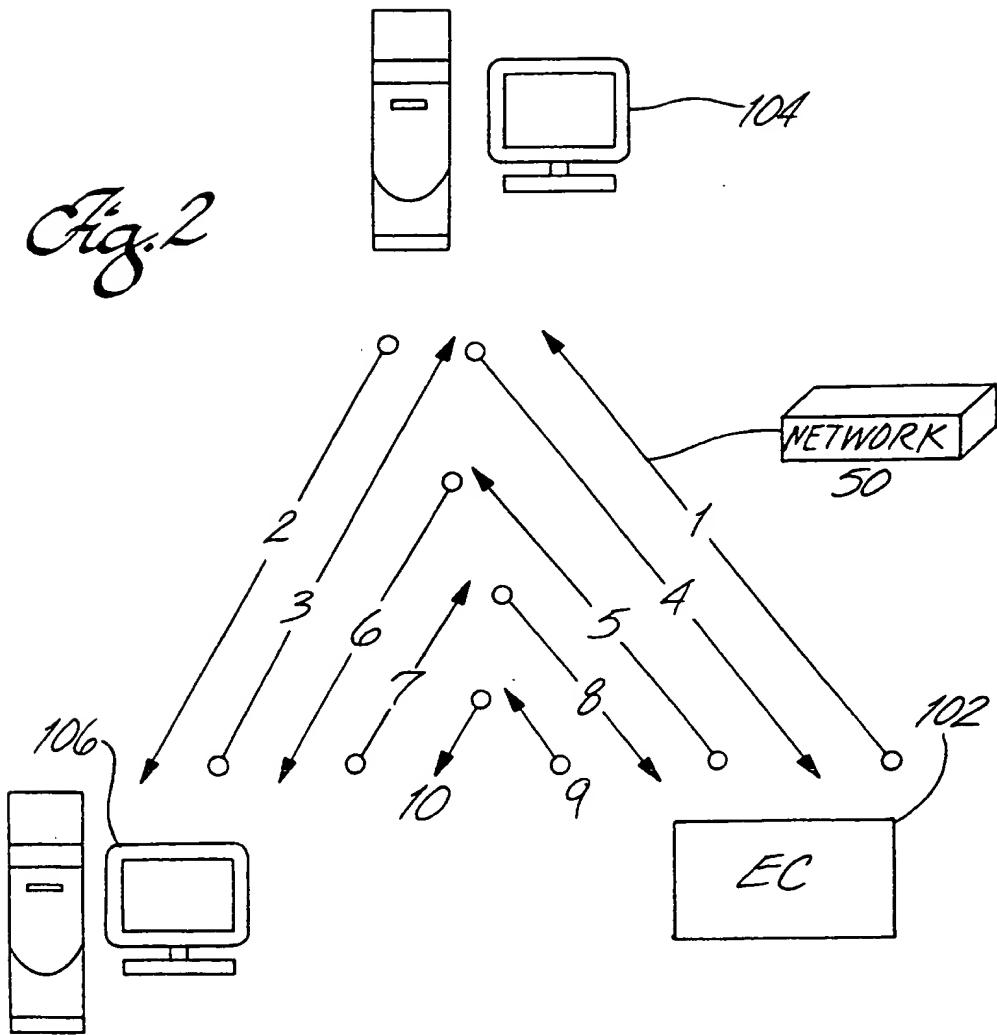
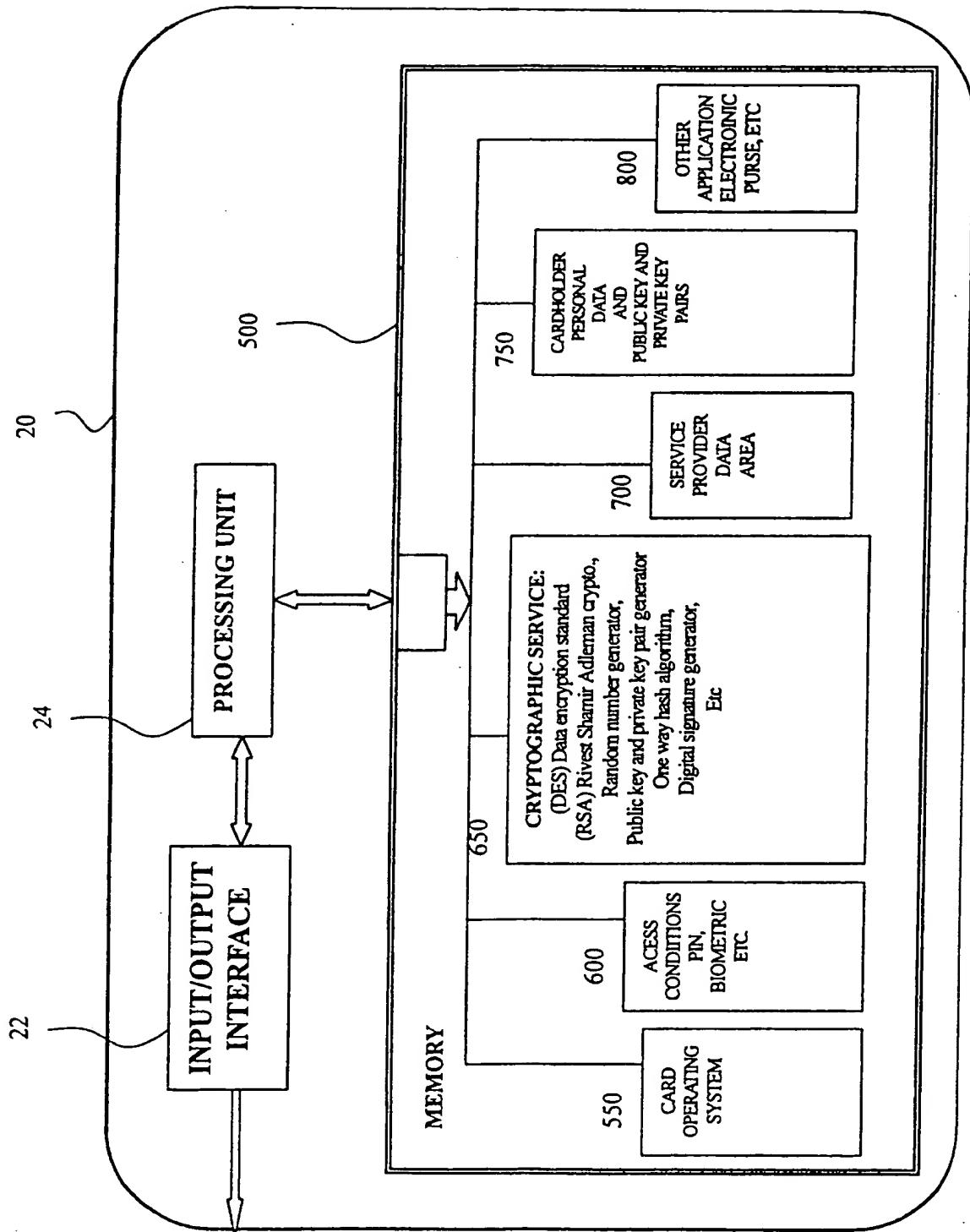
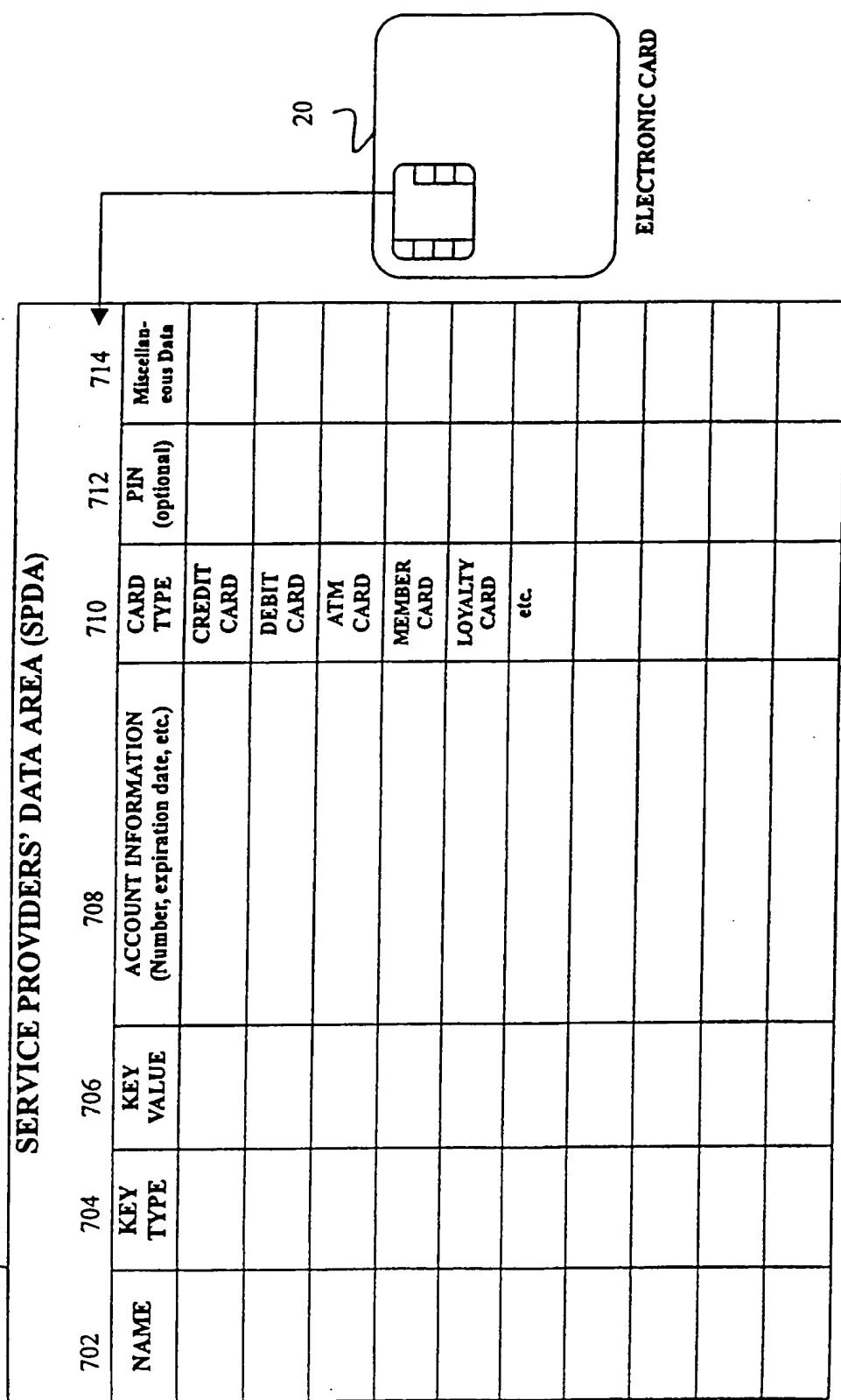
Fig. 2

FIG. 3

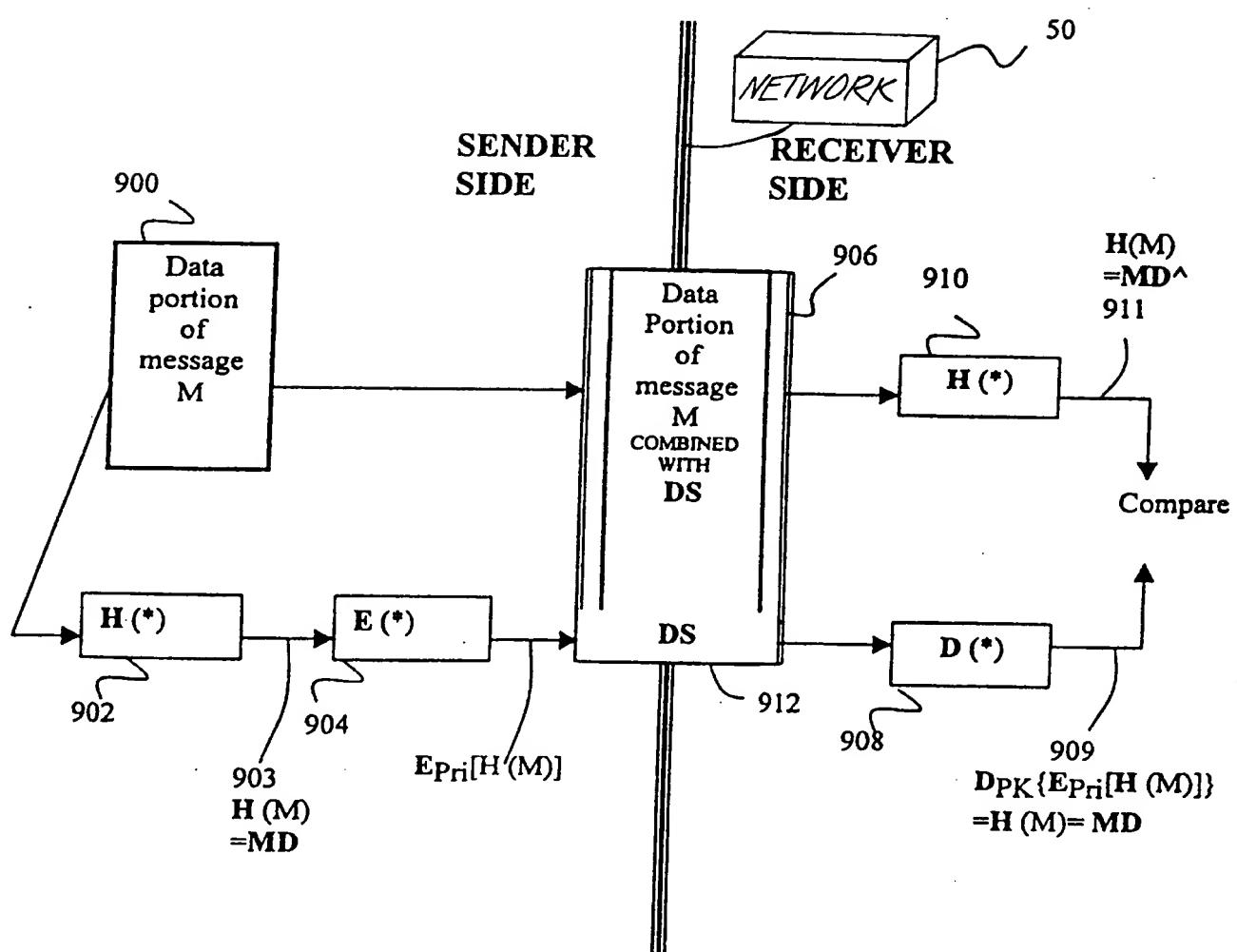


ELECTRONIC CARD

FIG. A

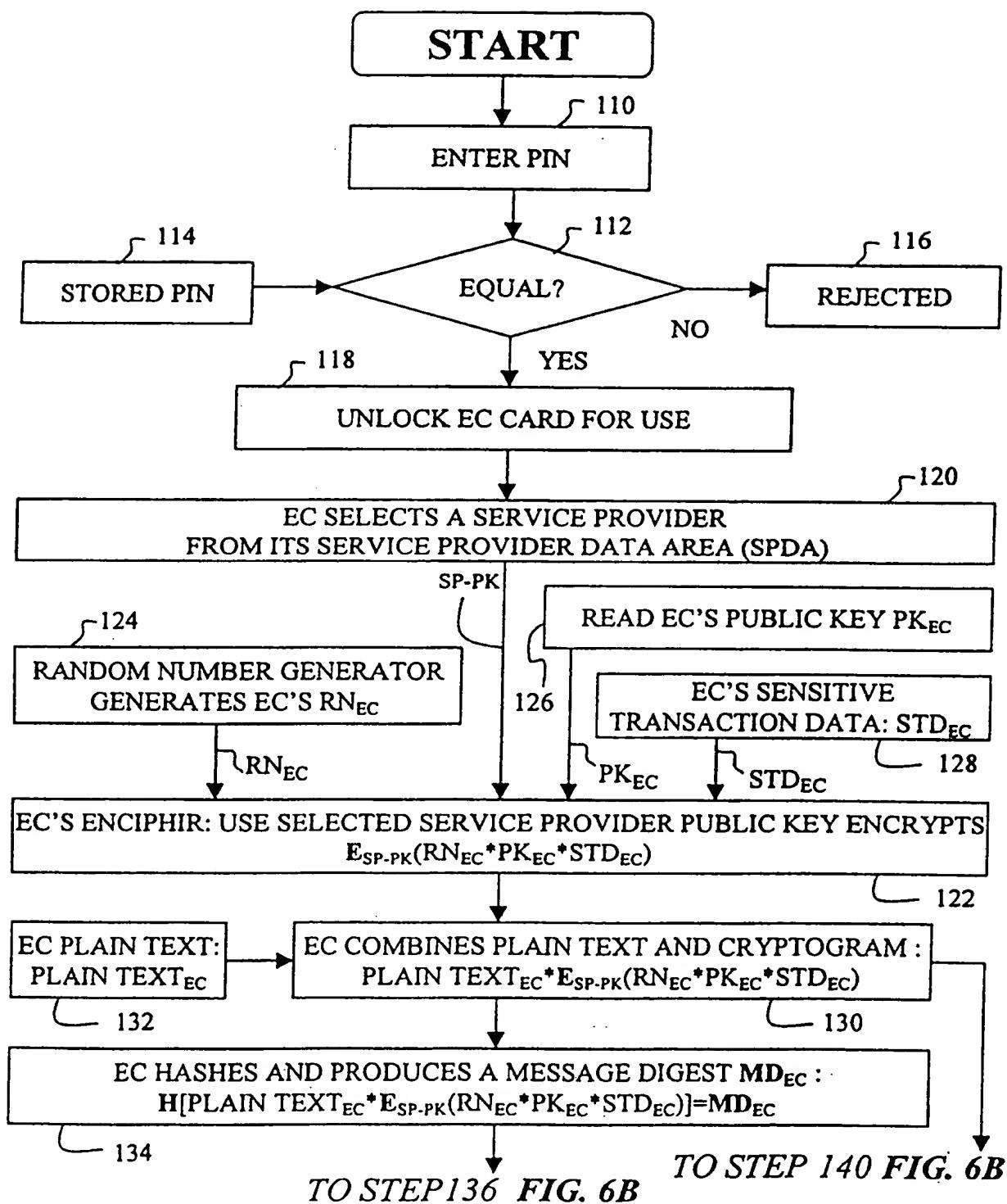


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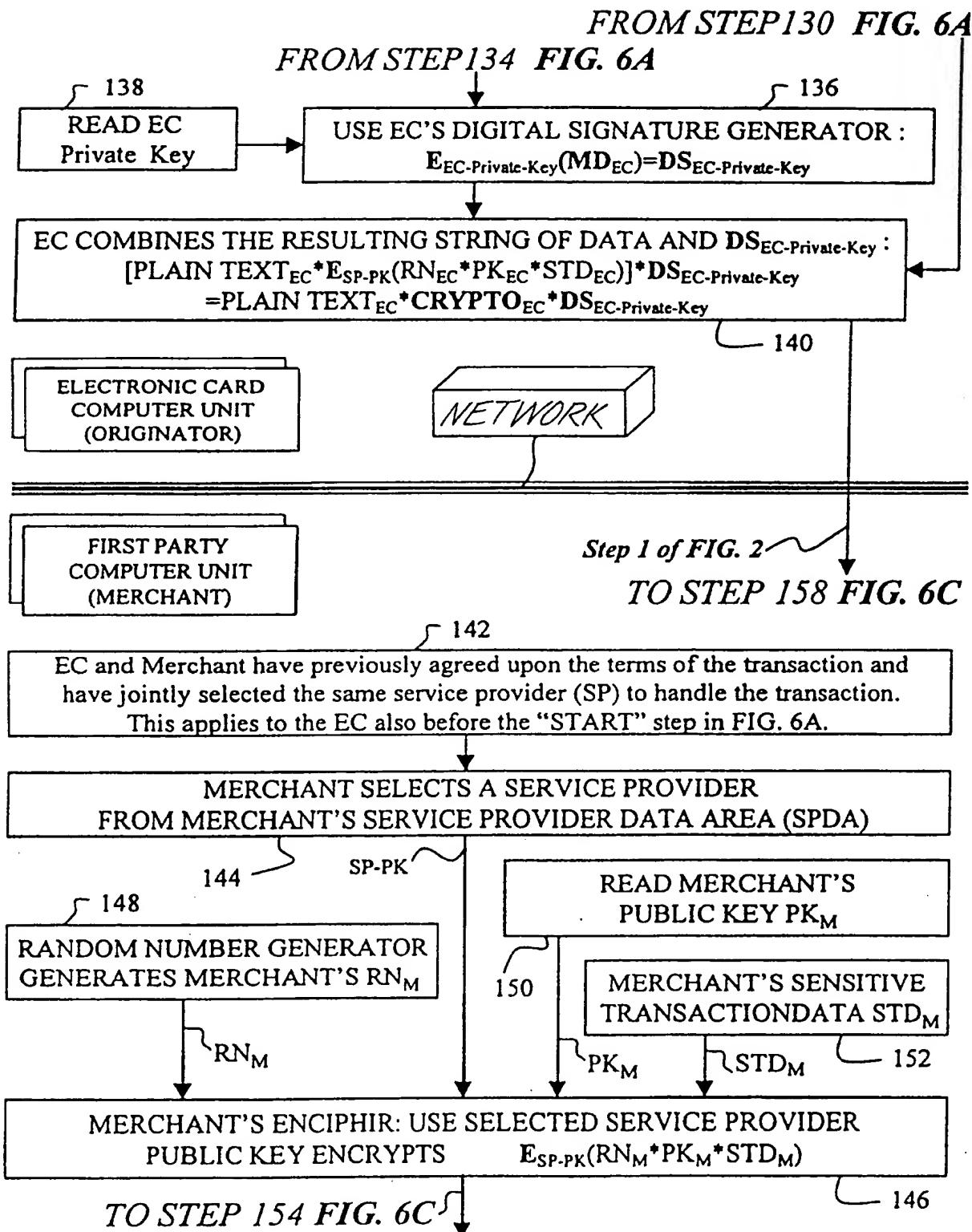
FIG. 5

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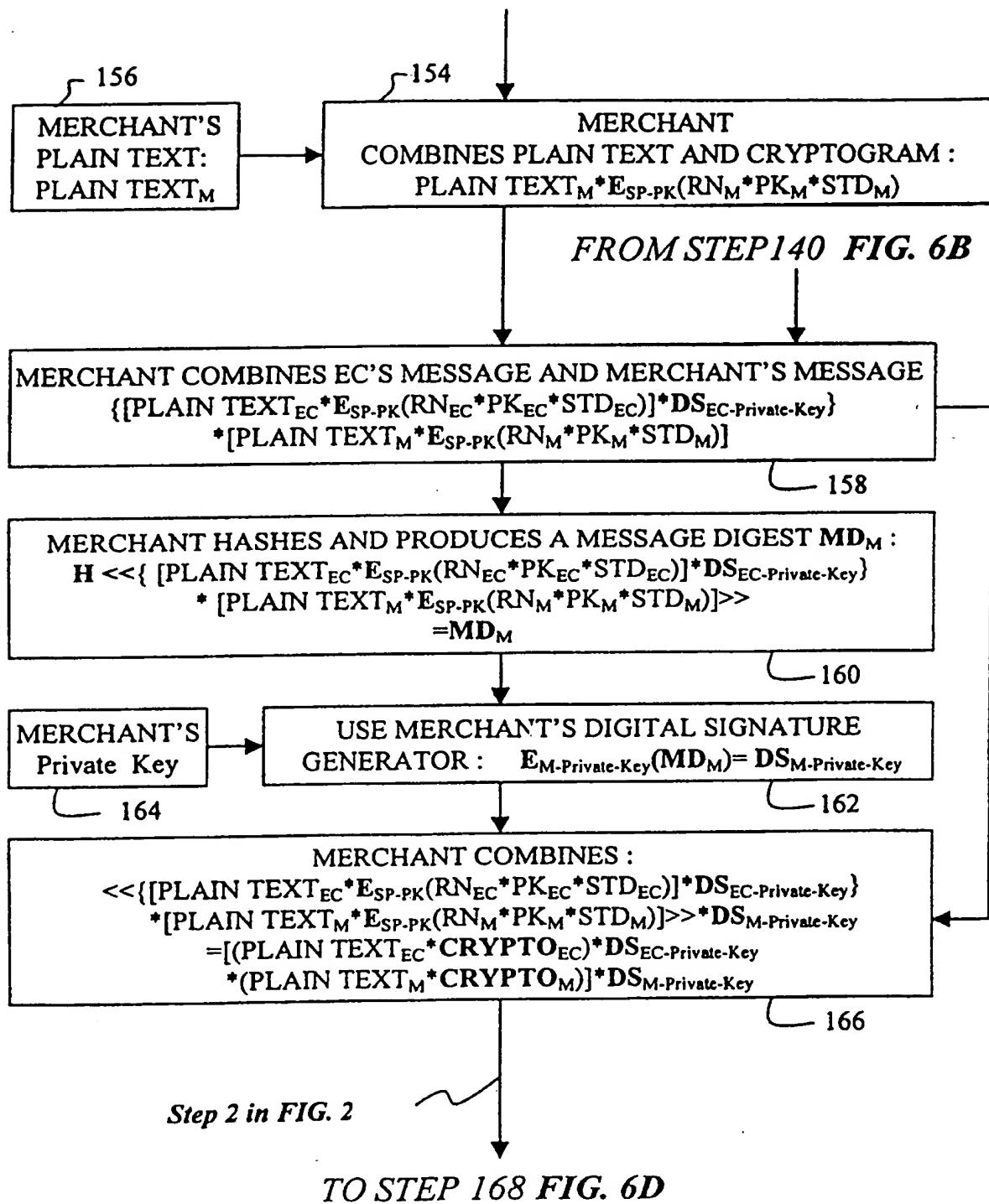
FIG. 6A



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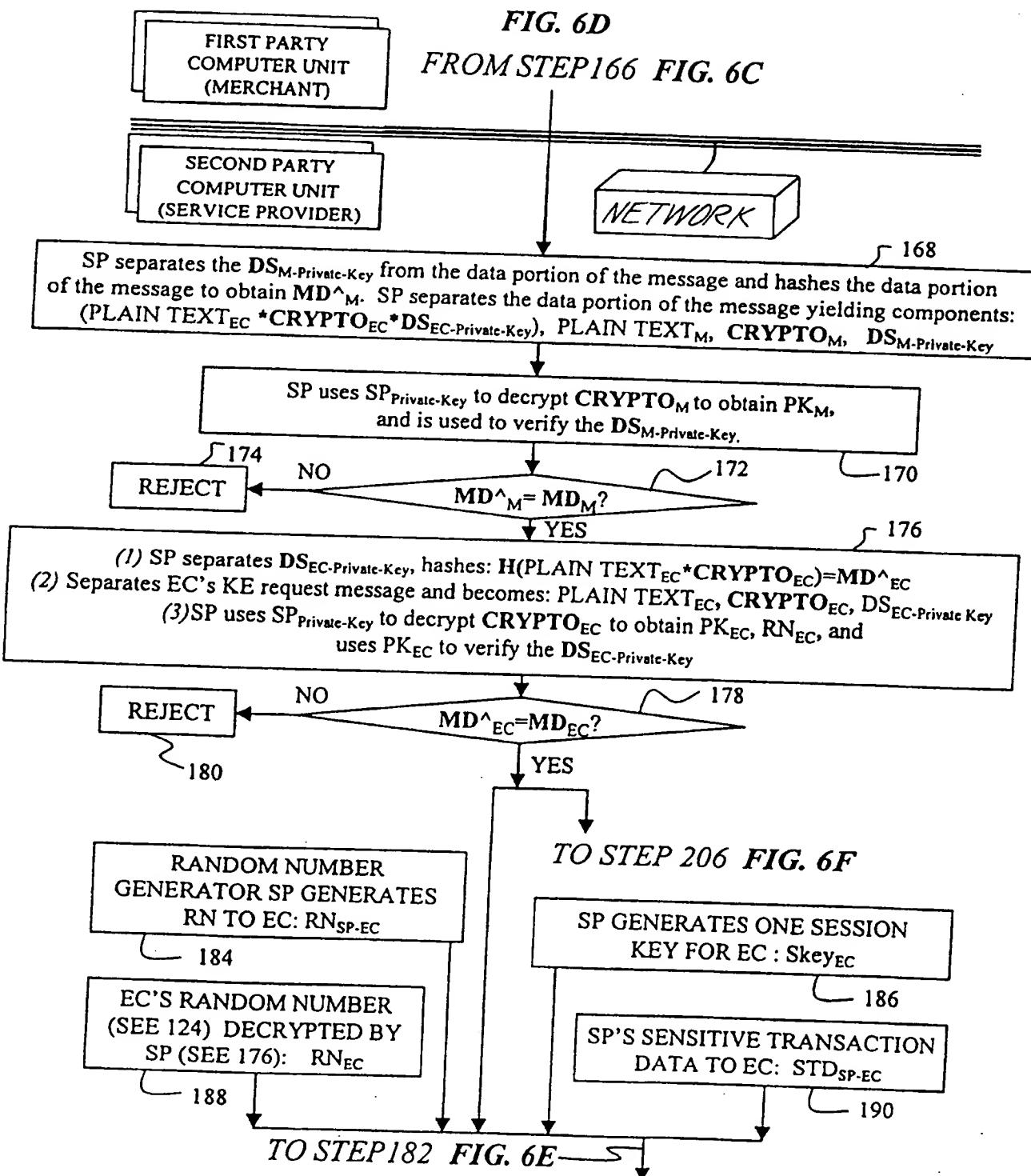
FIG. 6B

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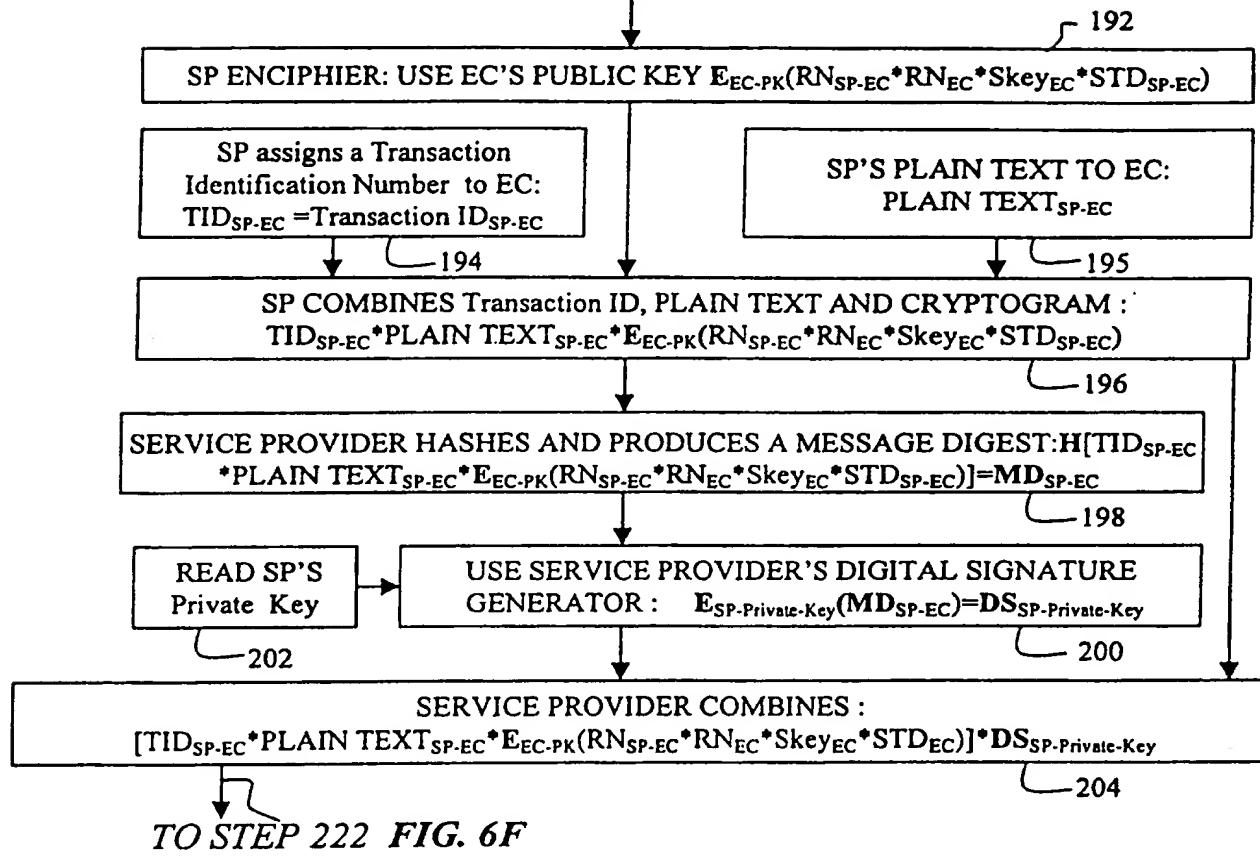
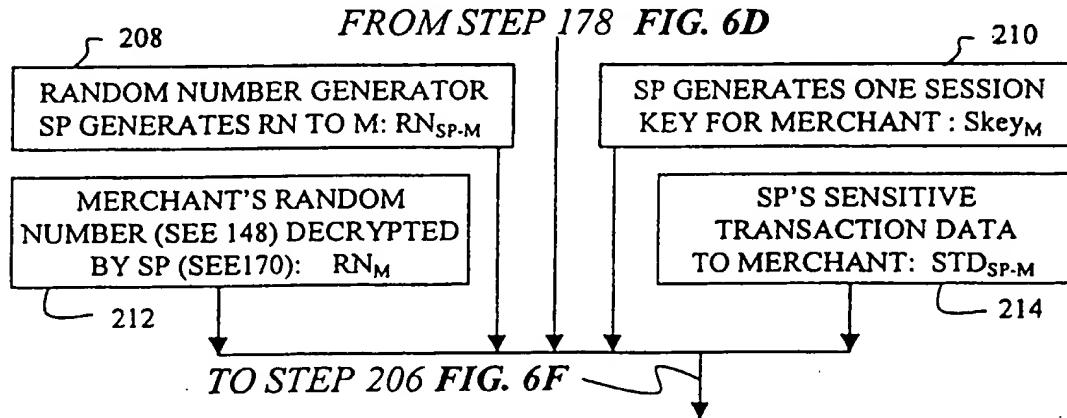
FIG. 6C*FROM STEP 146 FIG. 6B*

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FIG. 6D
FROM STEP 166 FIG. 6C

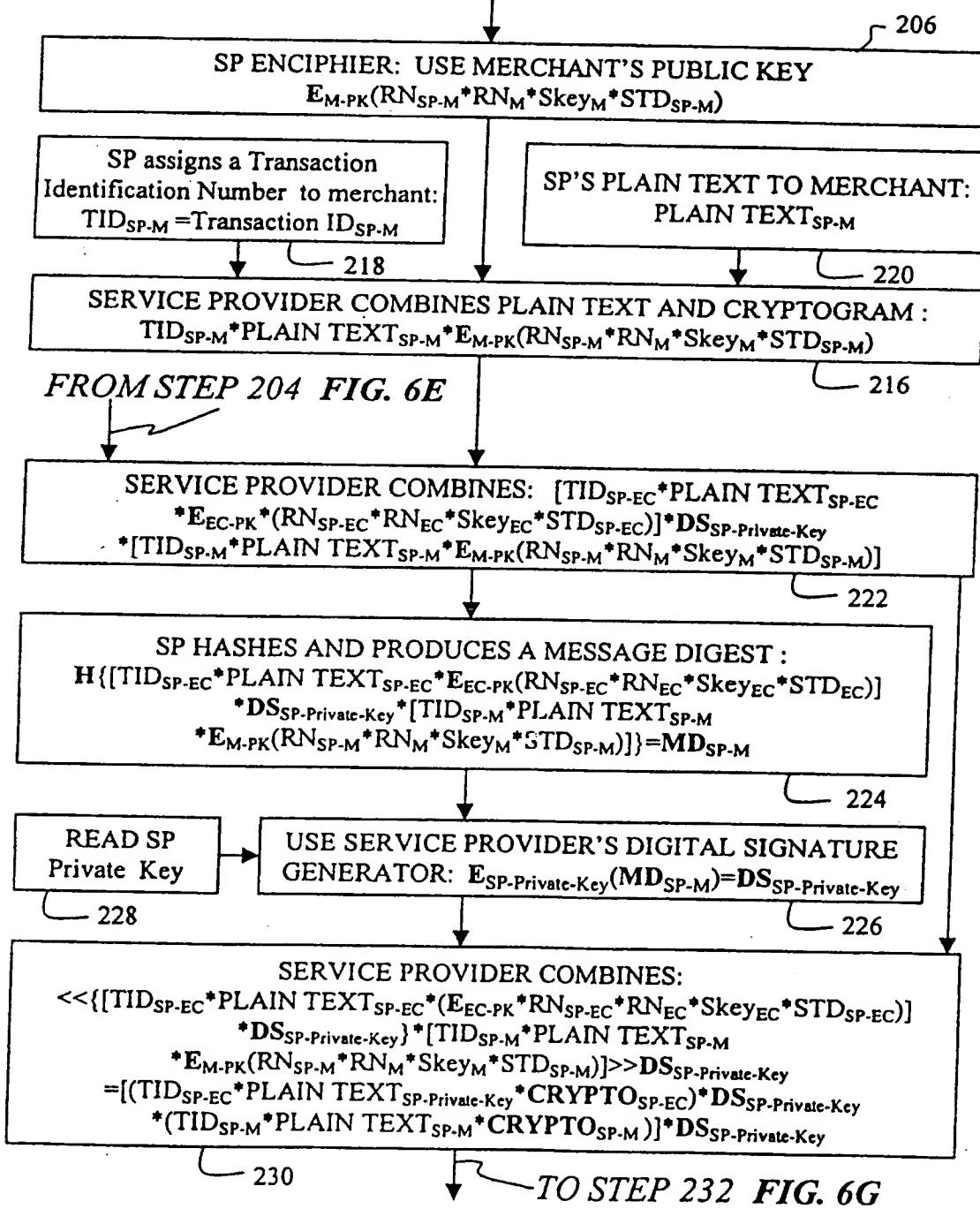


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FIG. 6E*FROM STEPS 184, 186, 188, 190 FIG. 6D**FROM STEP 178 FIG. 6D*

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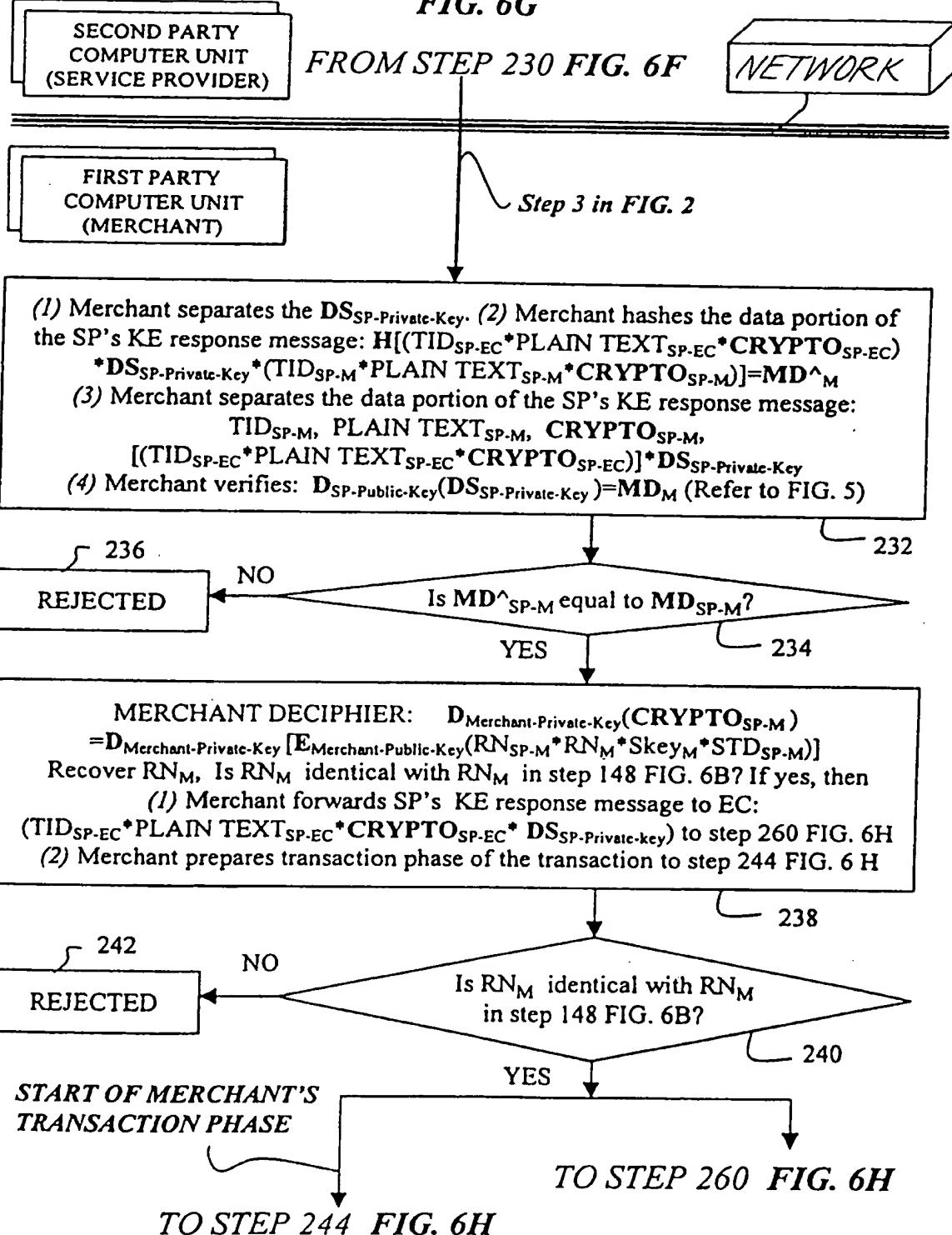
FIG. 6F
FROM STEPS 208, 210, 212, 214 FIG 6E



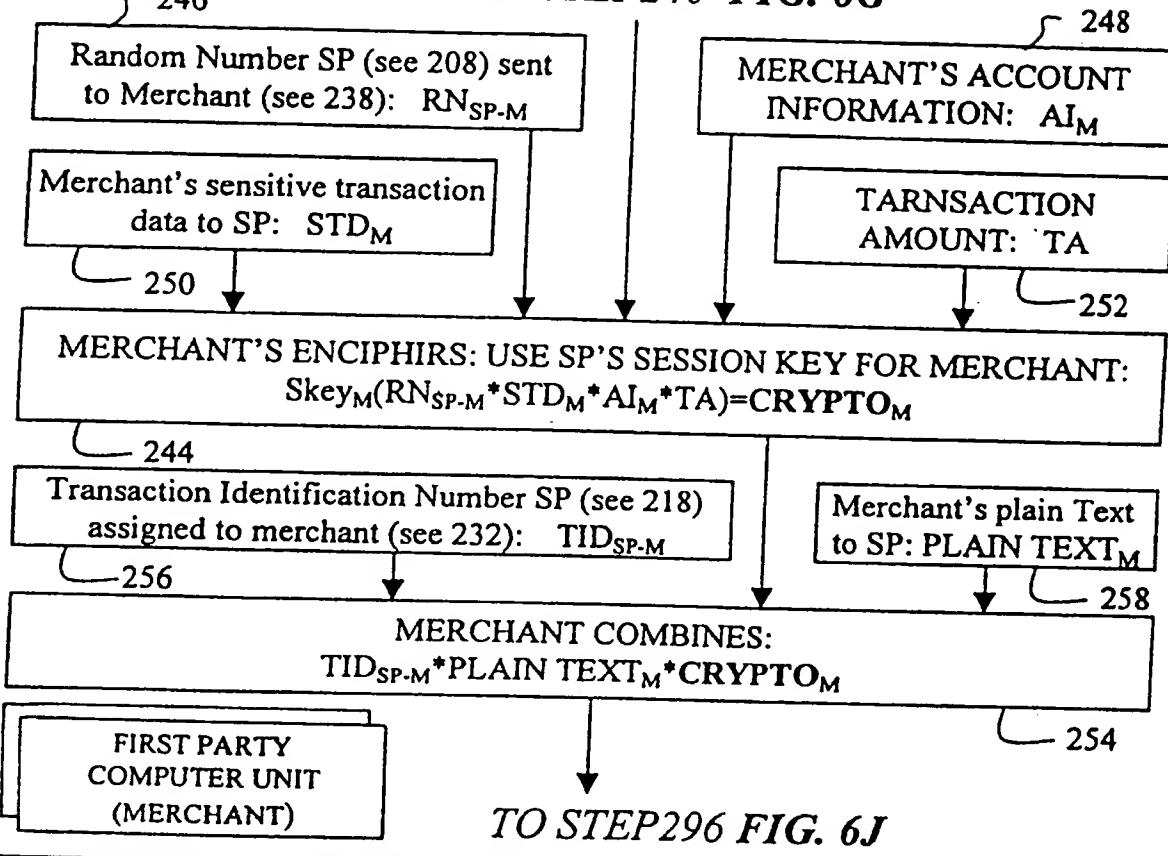
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FIG. 6G

FROM STEP 230 FIG. 6F



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FIG. 6H**FROM STEP240 FIG. 6G**

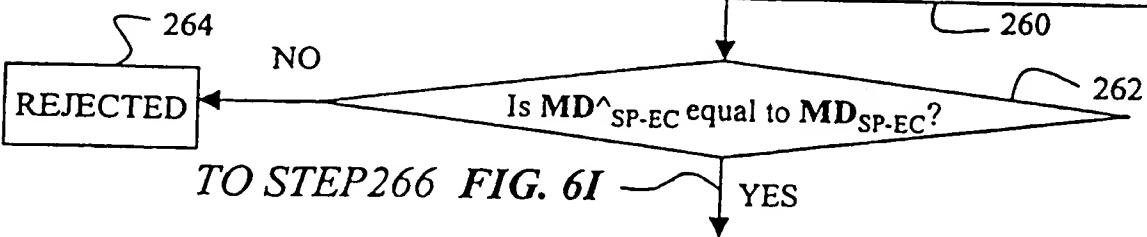
ELECTRONIC CARD COMPUTER UNIT (ORIGINATOR)

NETWORK

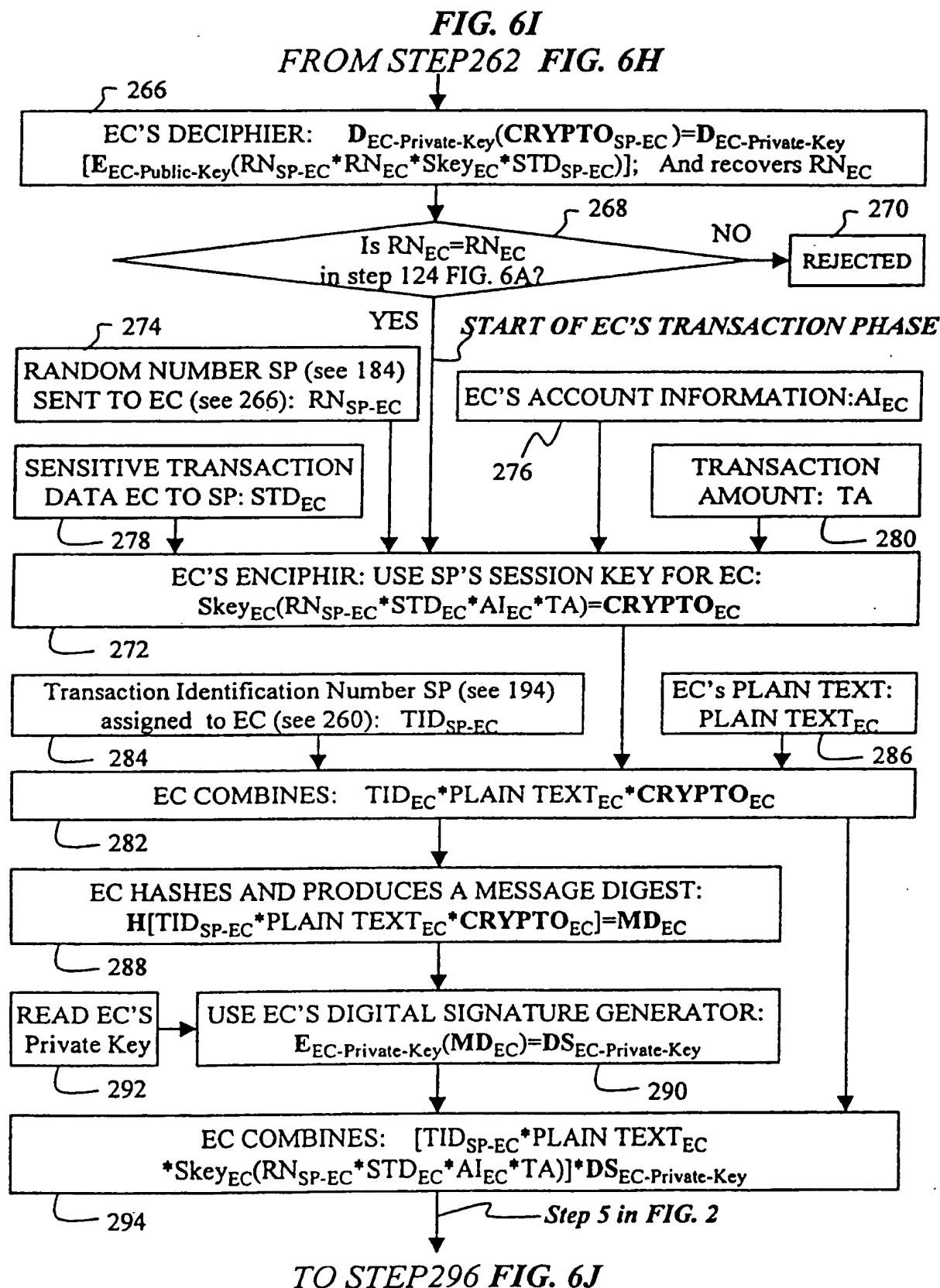
FROM STEP240 FIG. 6G

Step 4 in FIG. 2

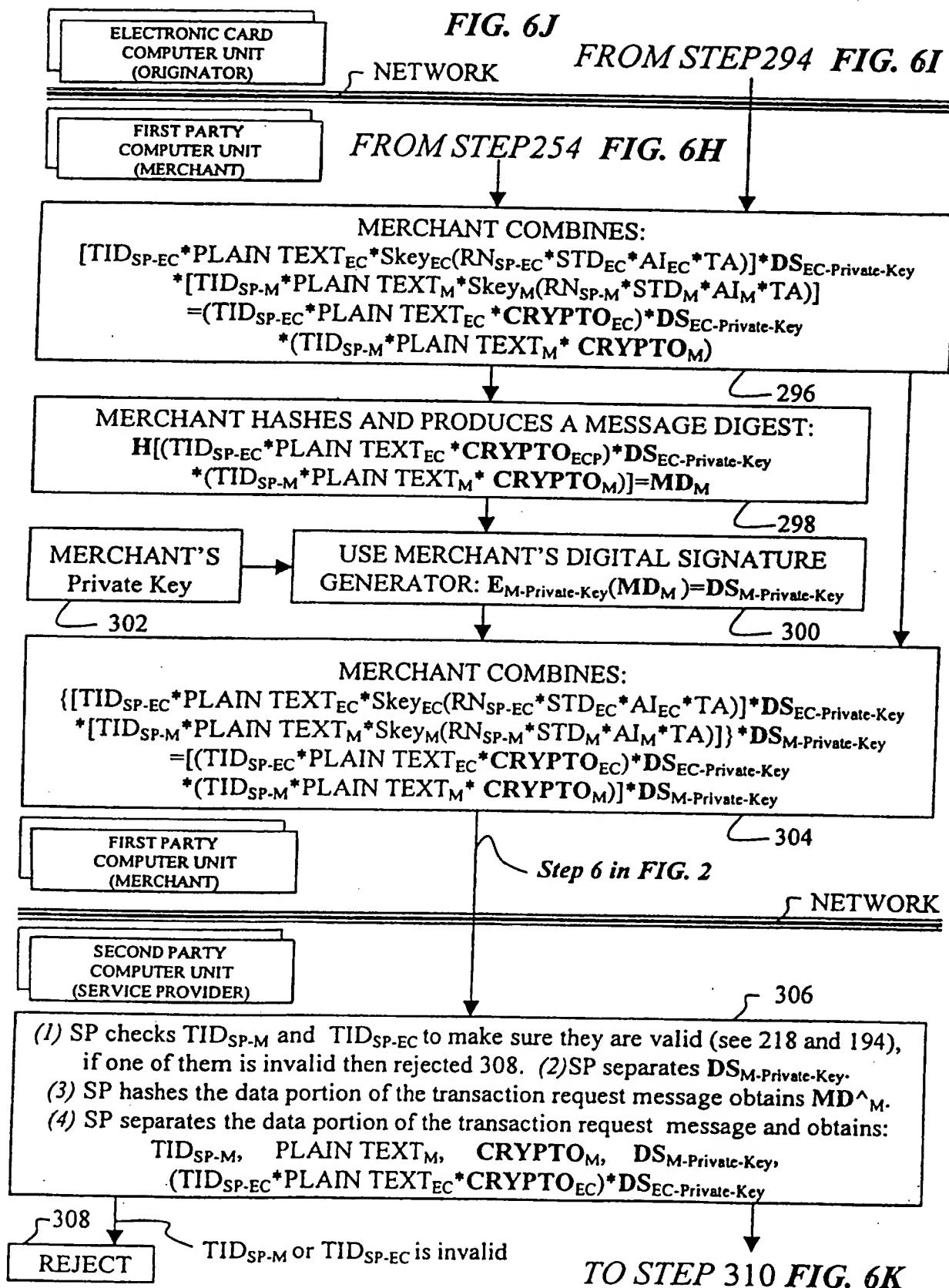
- (1) EC separates the DS_{SP-Private-Key}, and hashes the data portion of the message:
 $H(TID_{SP-EC} * PLAIN TEXT_{SP-EC} * CRYPTO_{SP-EC}) = MD^{SP-EC}$
- (2) EC separates: TID_{SP-EC}, PLAIN TEXT_{SP-EC}, CRYPTO_{SP-EC}, DS_{SP-Private-key}
- (3) EC verifies: D_{SP-public-Key} (DS_{SP-Private-Key}) = MD_{SP-EC} (Refer to FIG.5)



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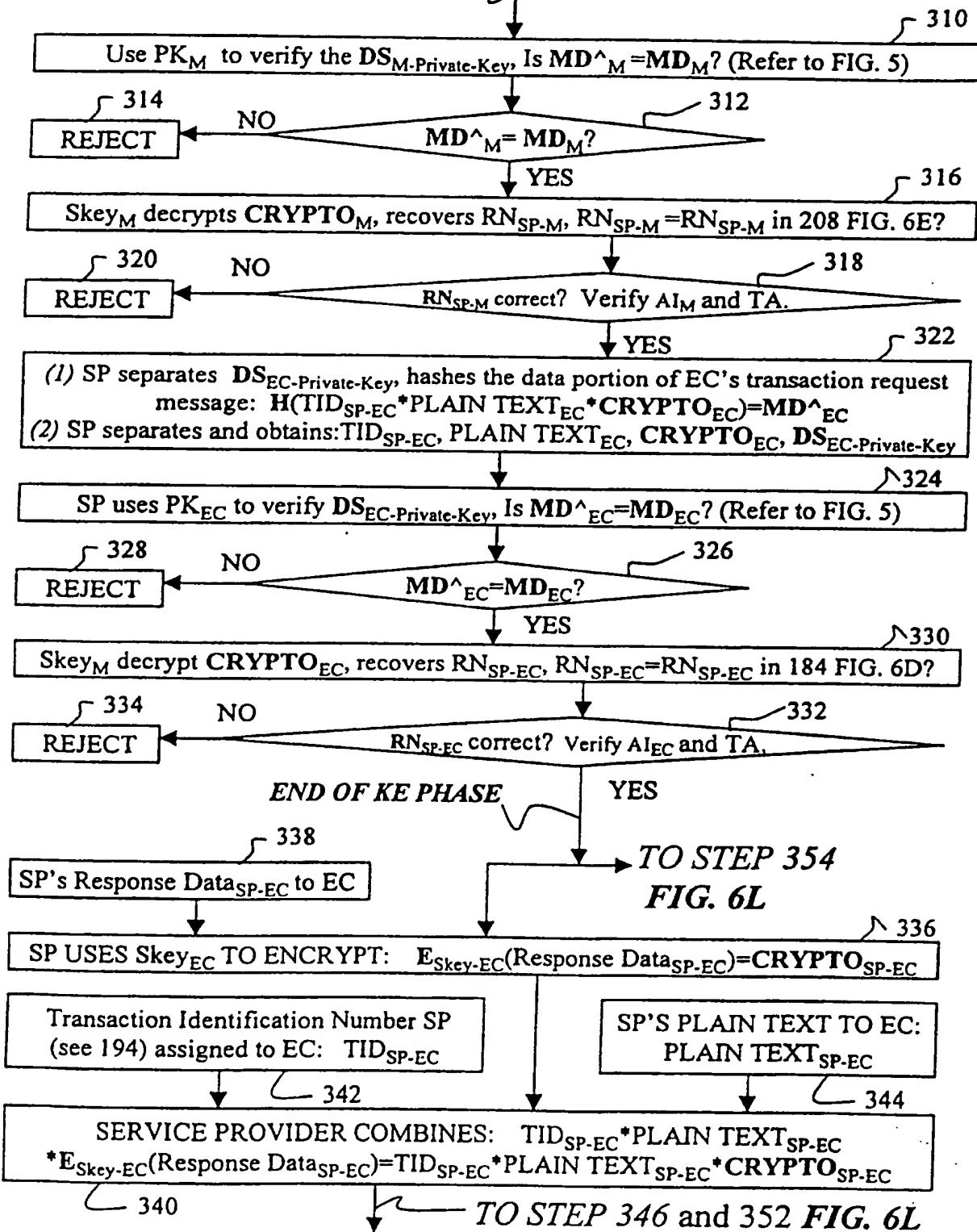


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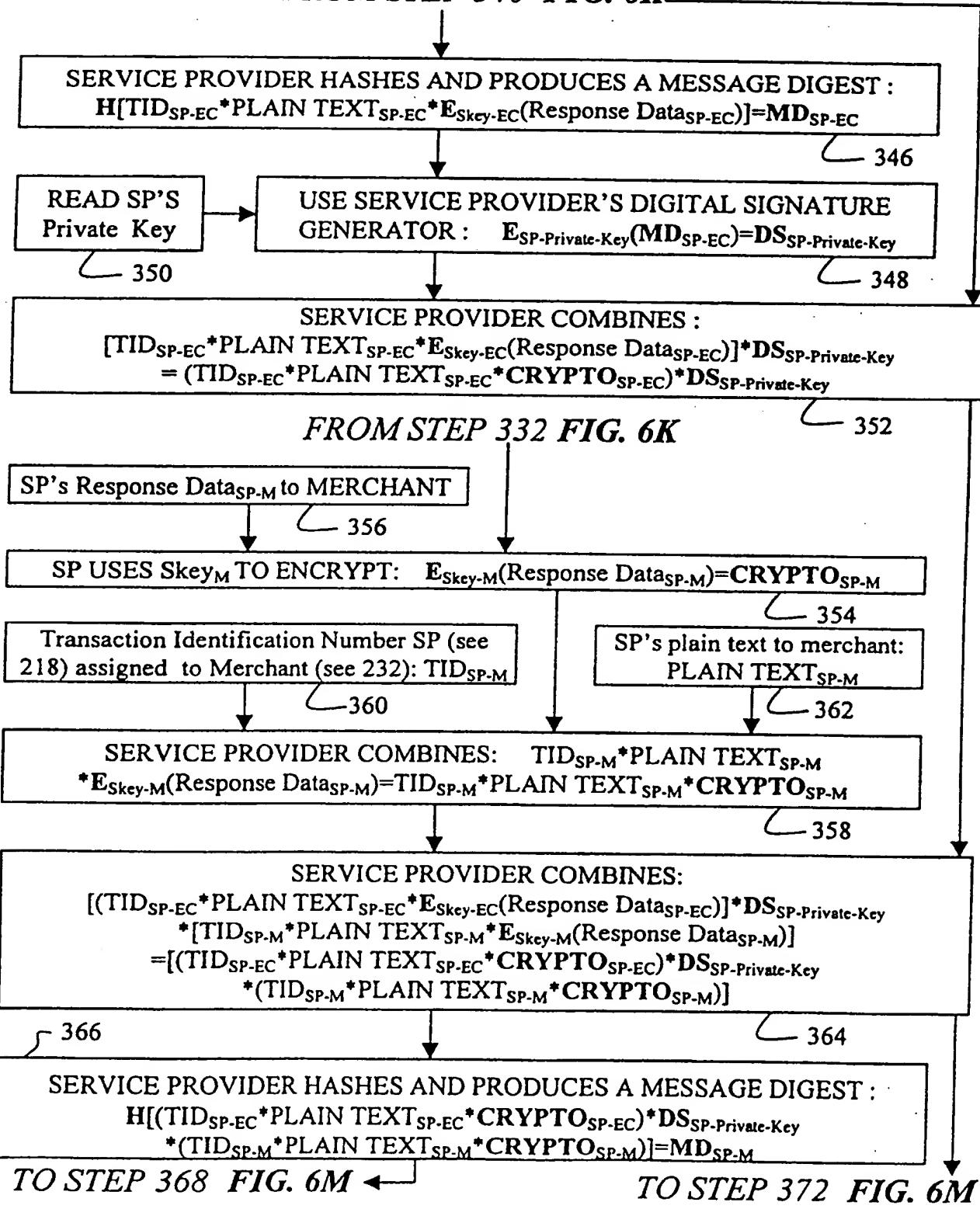


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FIG. 6K
FROM STEP 306 FIG. 6J



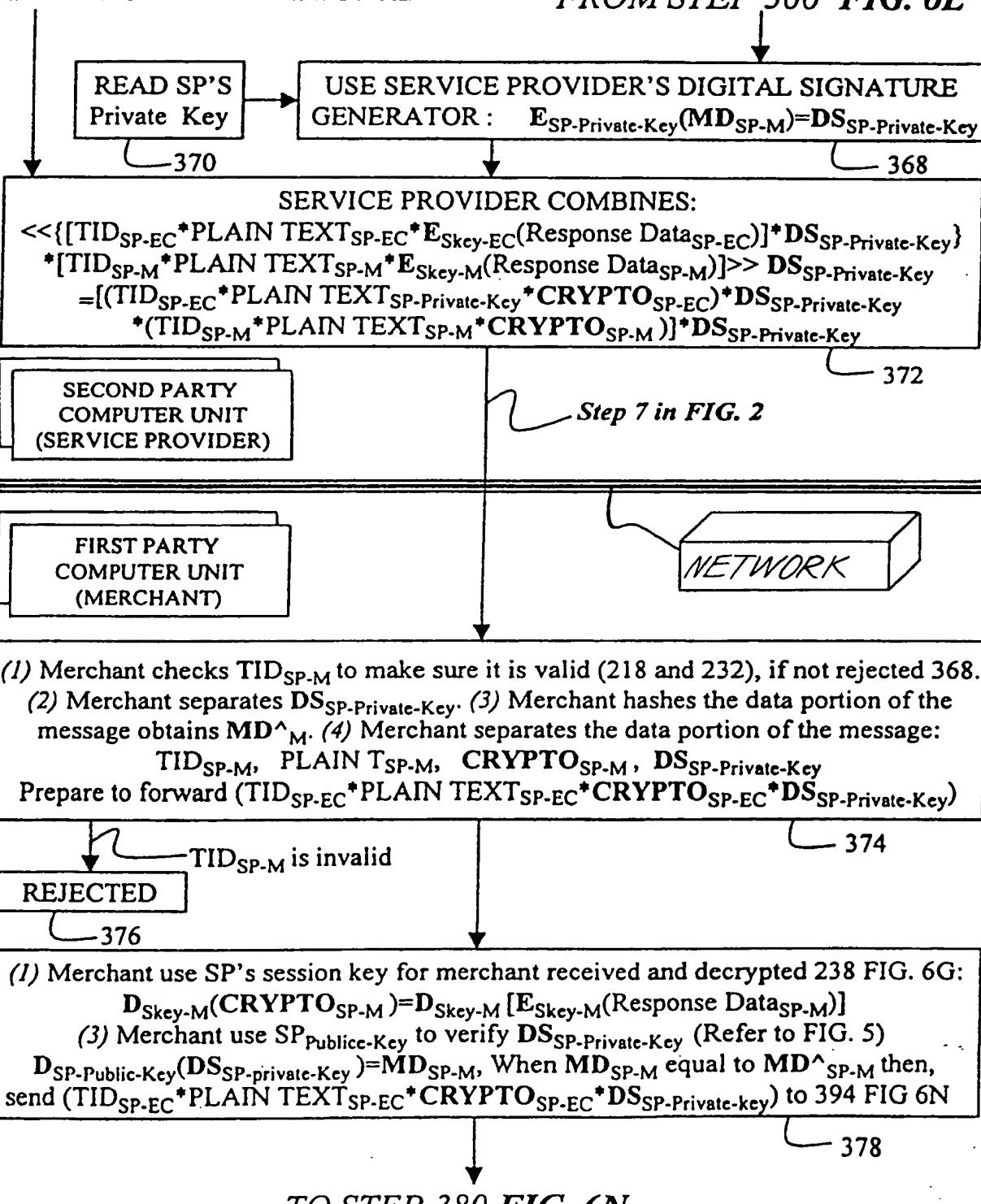
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FIG. 6L*FROM STEP 340 FIG. 6K*

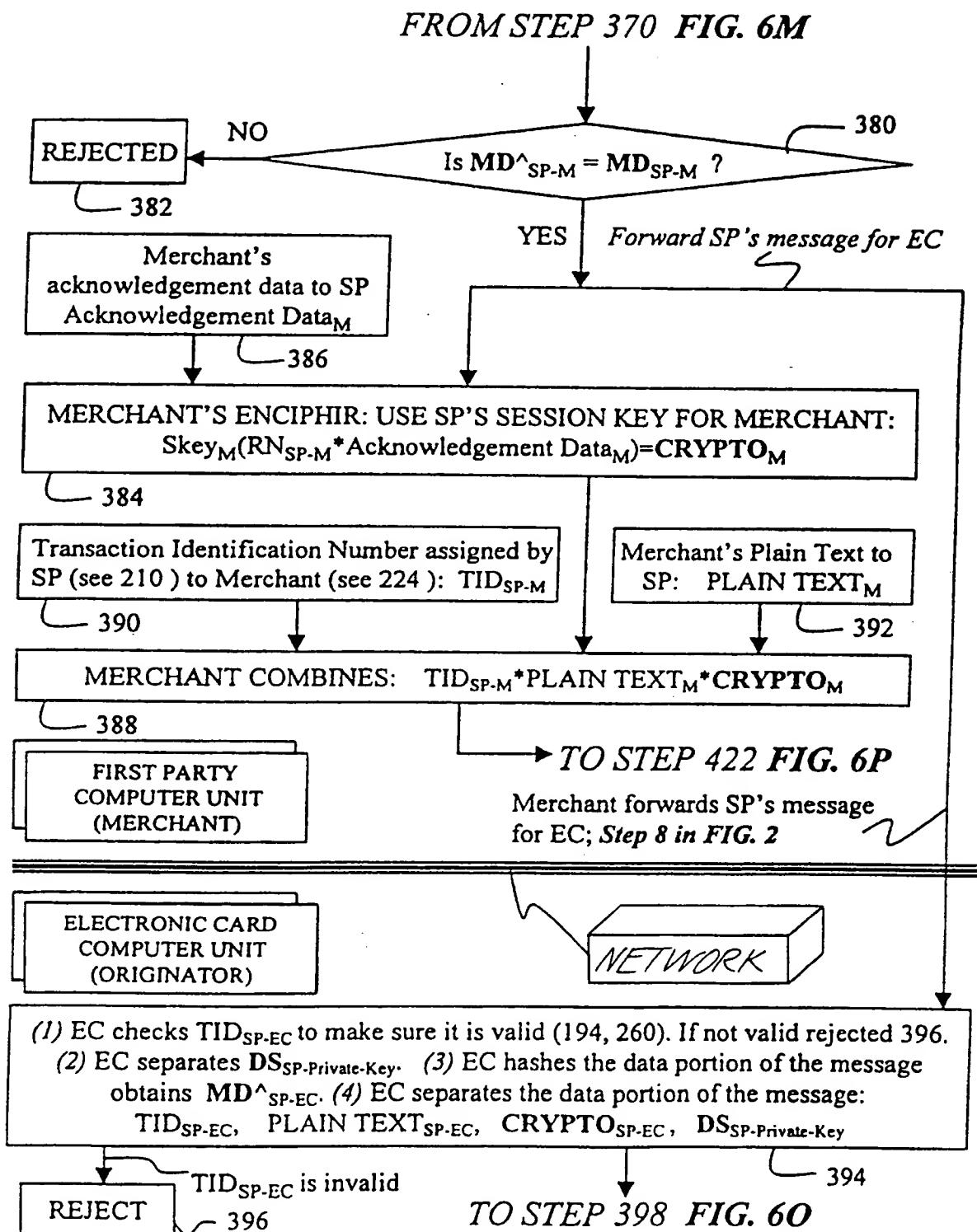
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FIG. 6M

FROM STEP 364 FIG. 6L



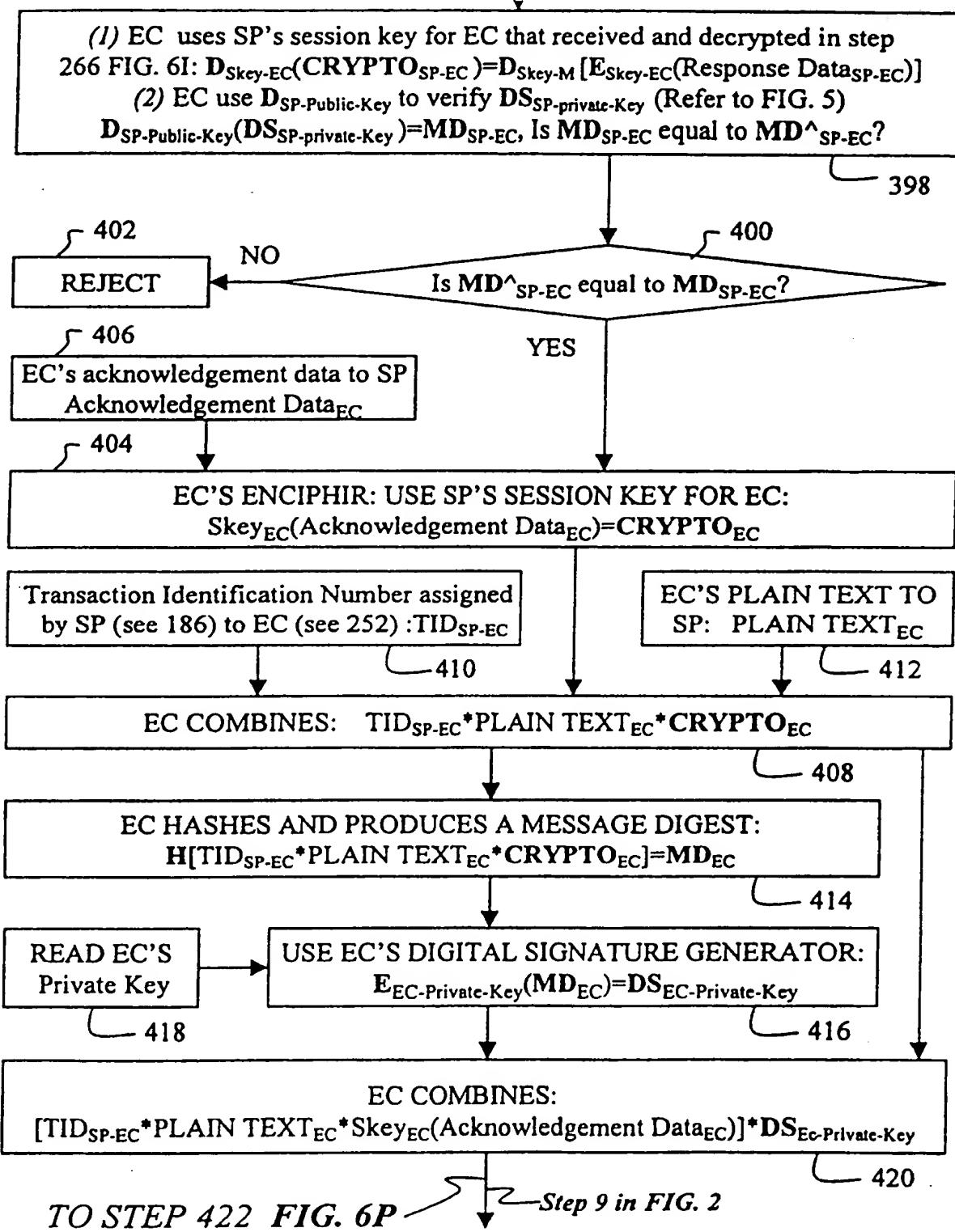
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FIG. 6N

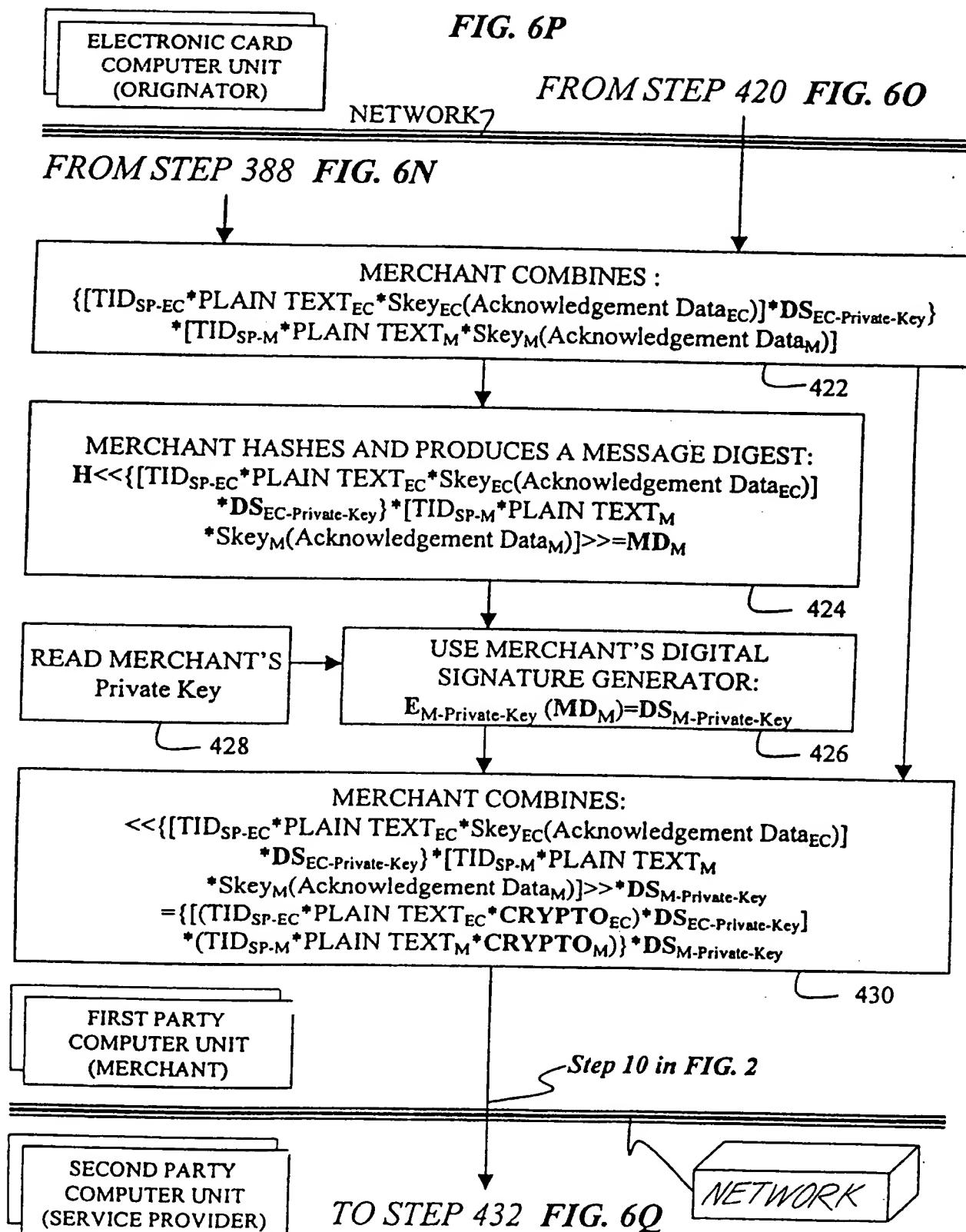
20/29

FIG. 6O

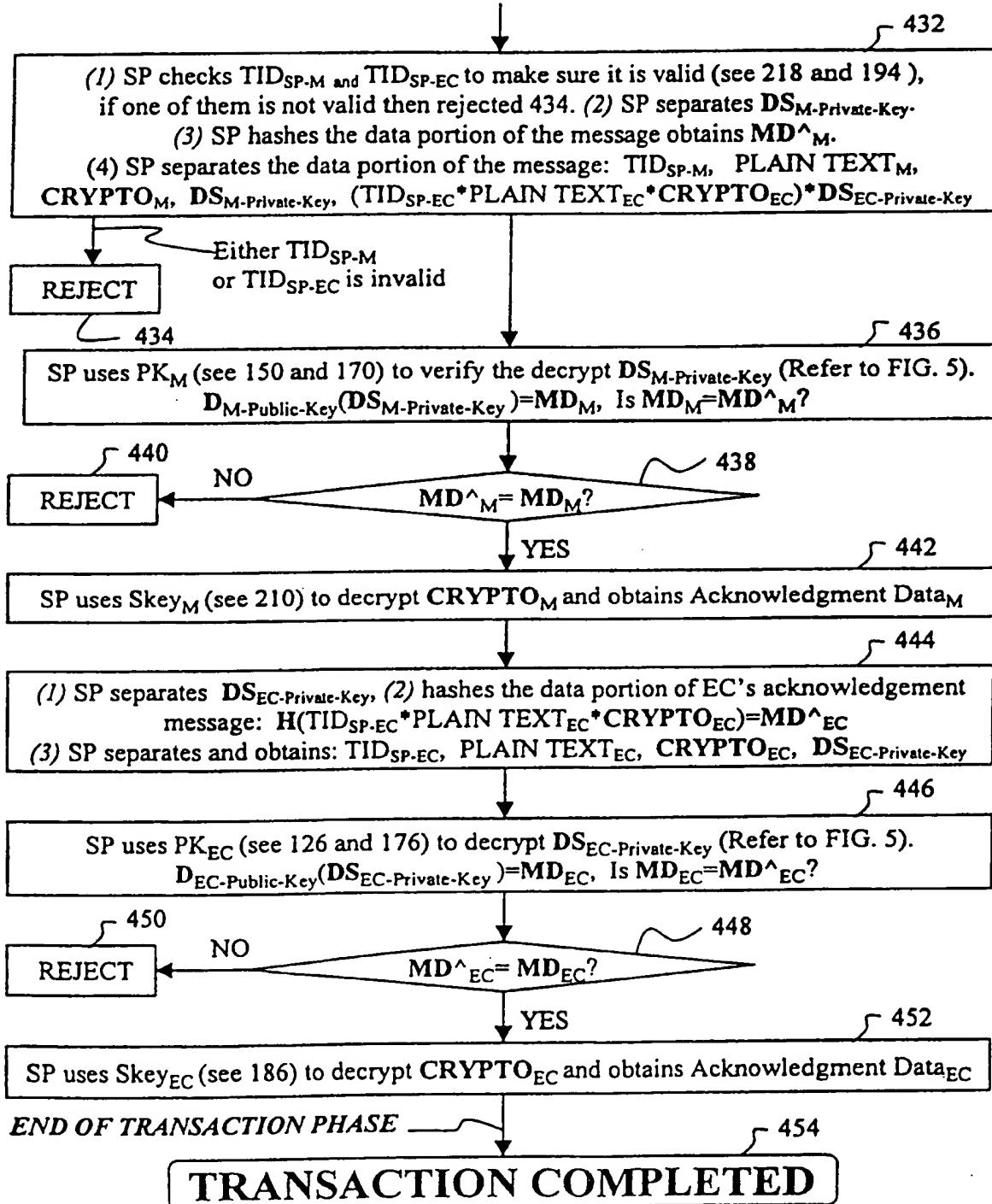
FROM 394 FIG. 6N



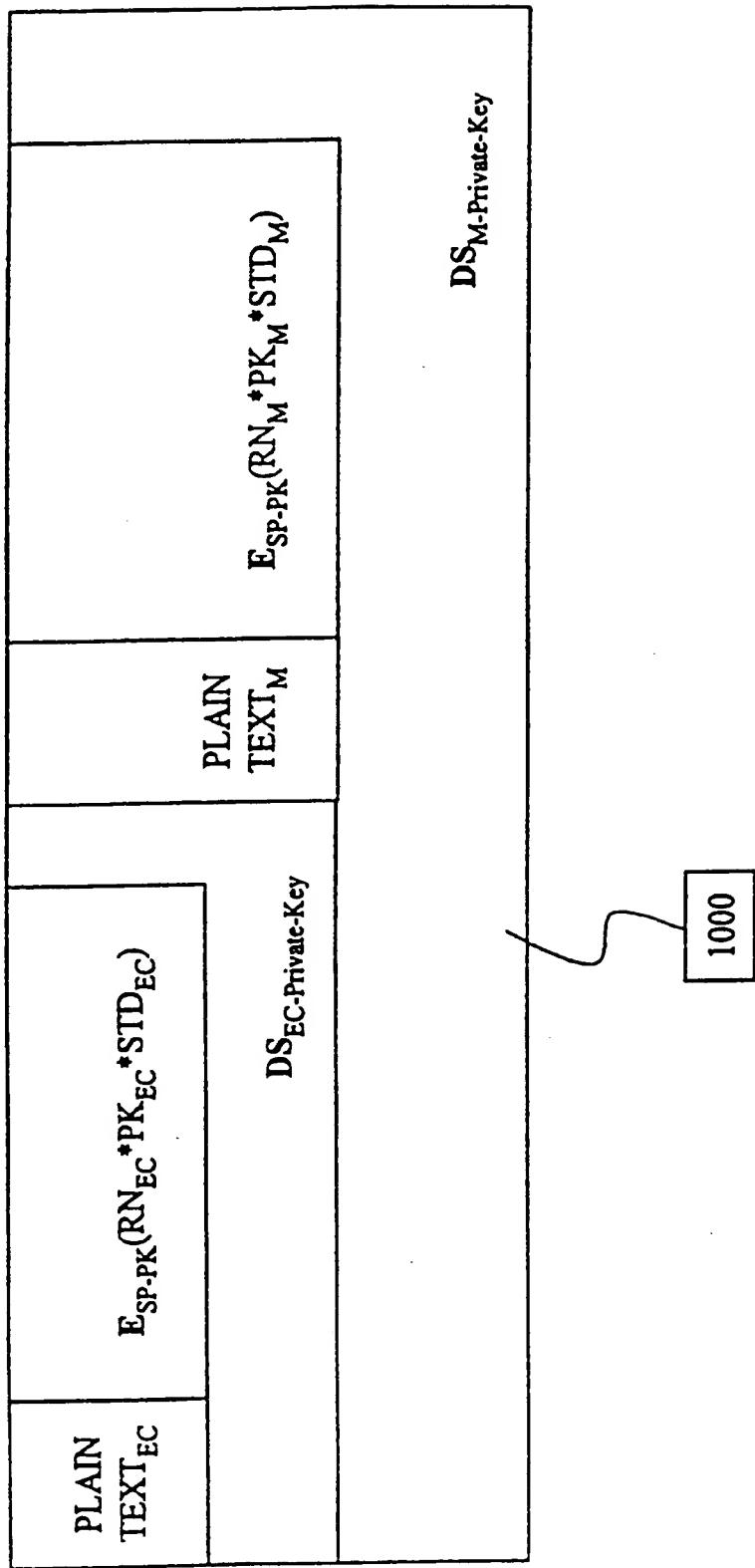
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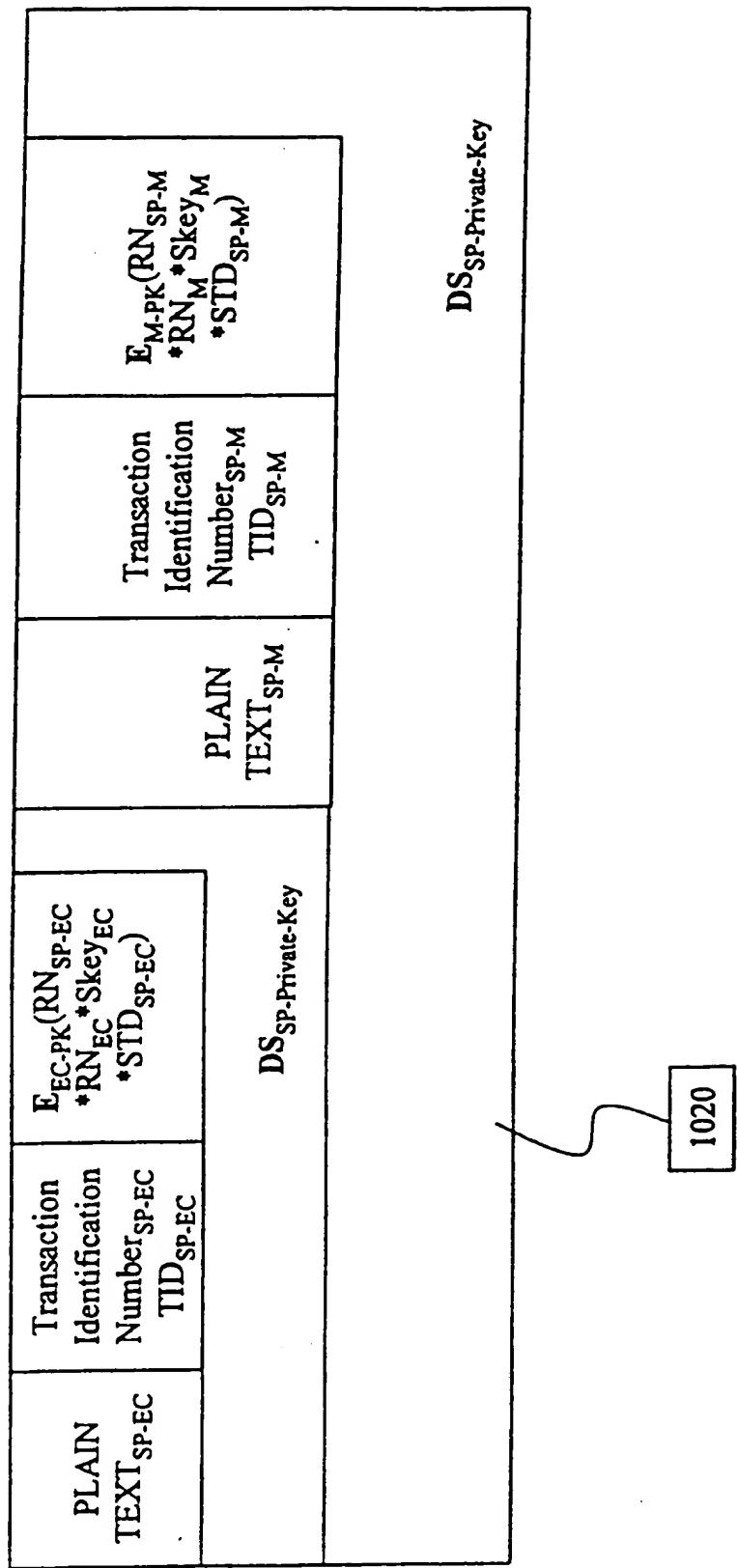
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FIG. 6Q*FROM STEP 430 FIG. 6P*

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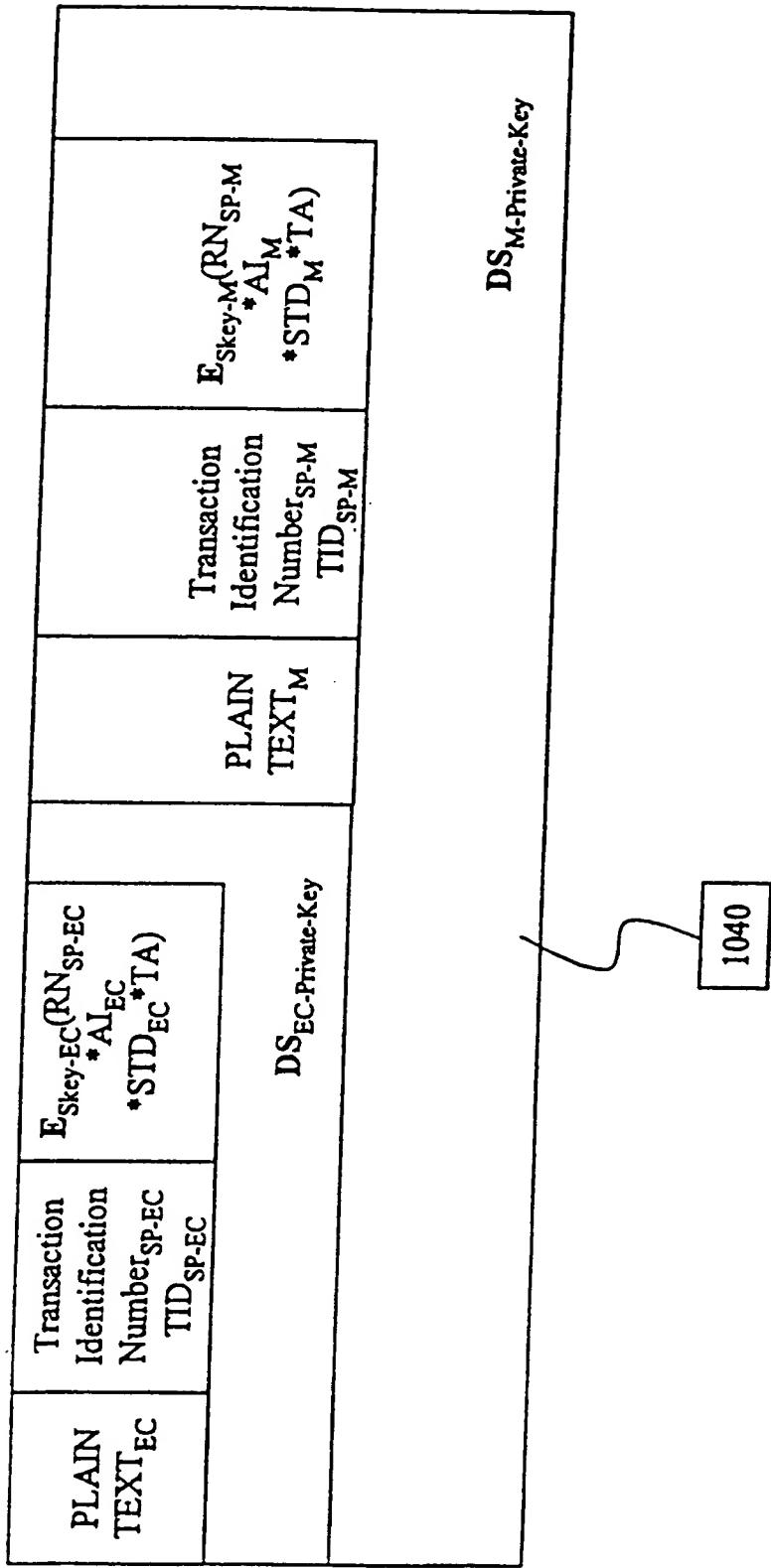
FIG. 7

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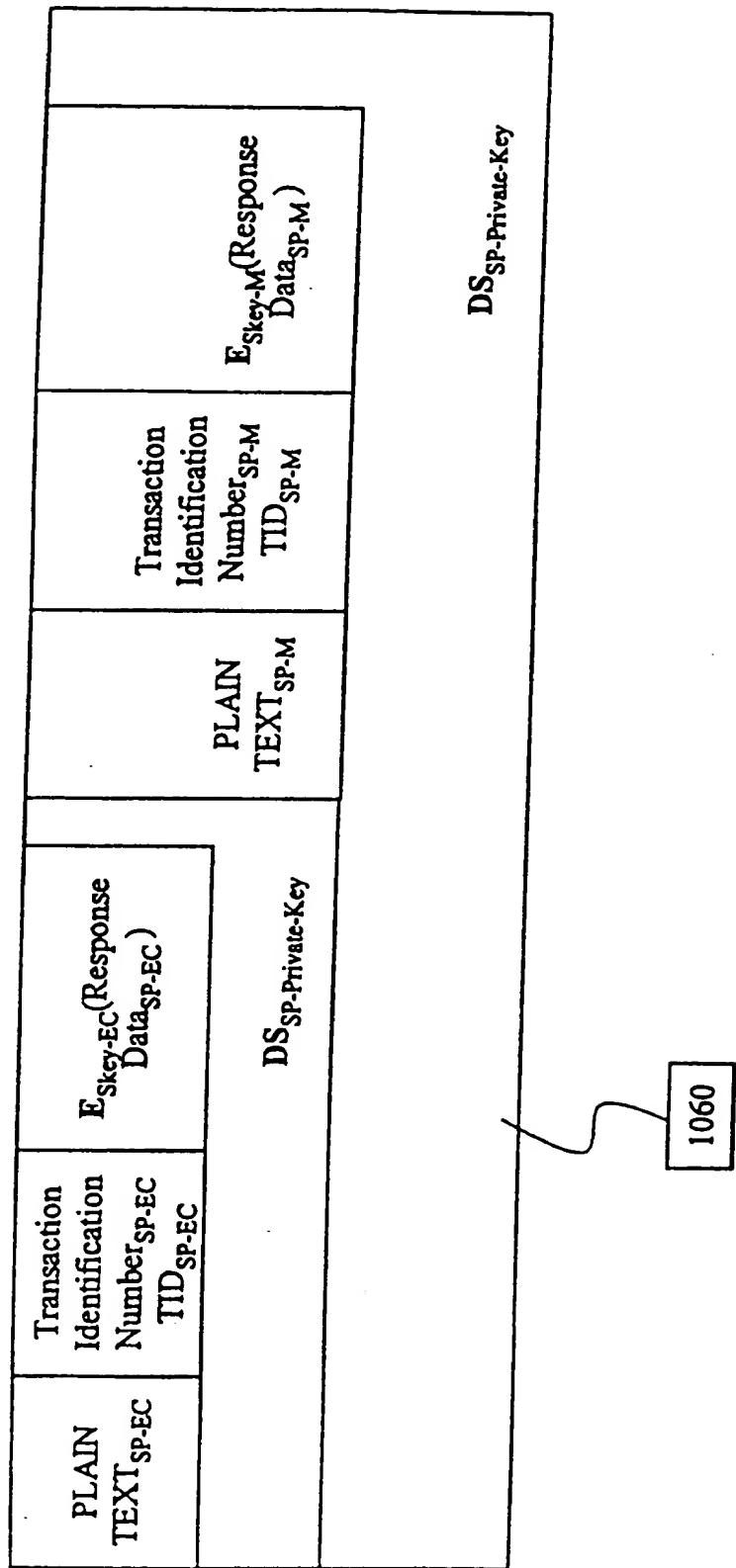
FIG. 8**SUBSTITUTE SHEET (RULE 26)**

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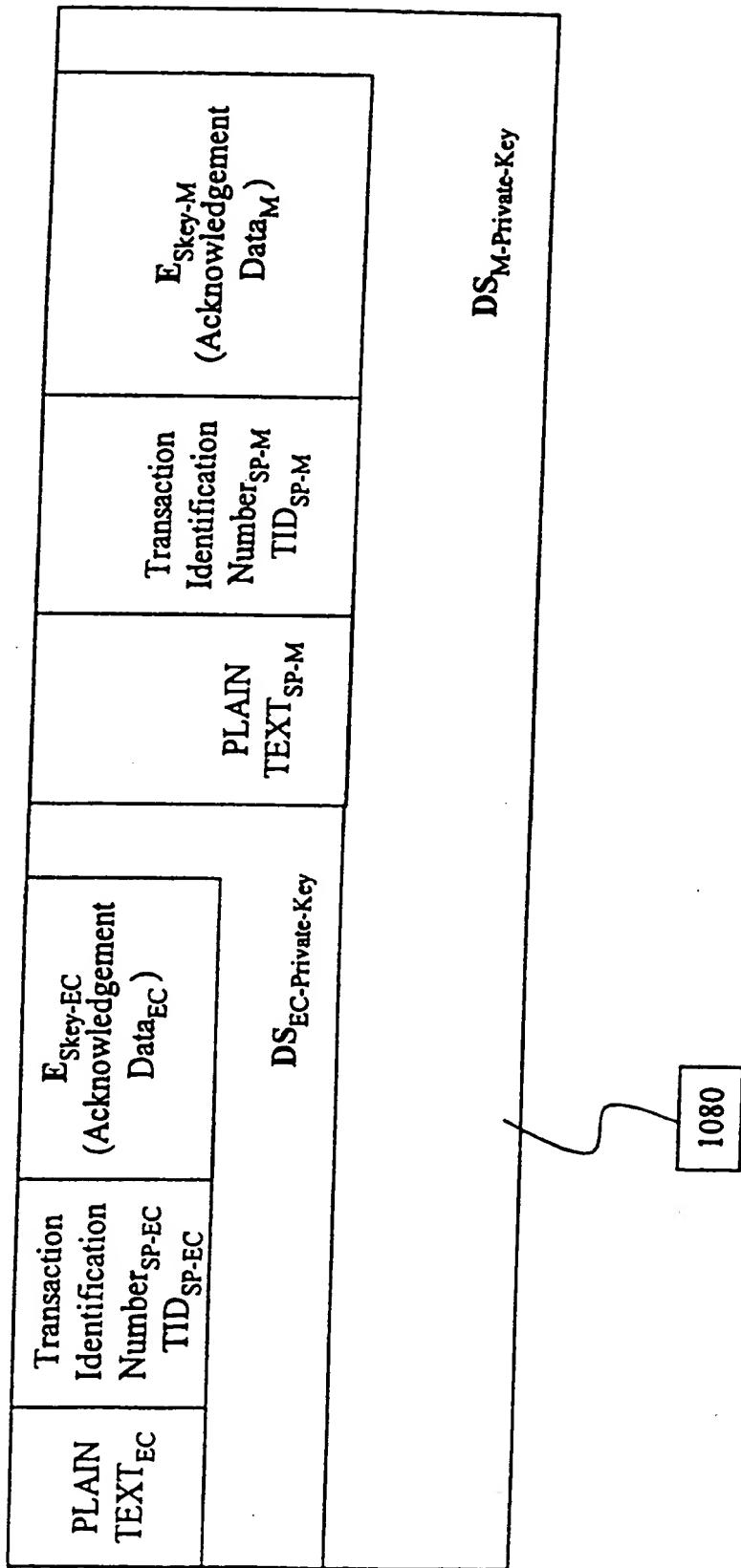
FIG.9



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FIG.10**SUBSTITUTE SHEET (RULE 26)**

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FIG.11

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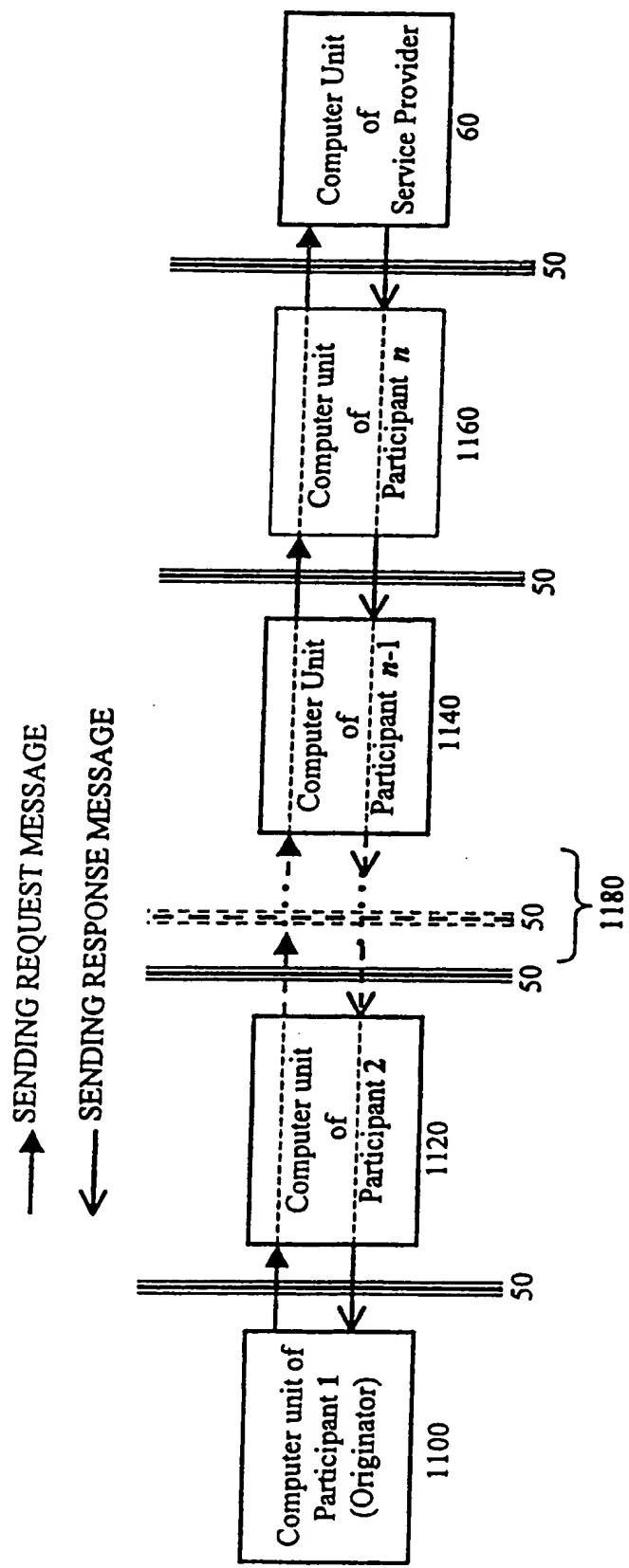
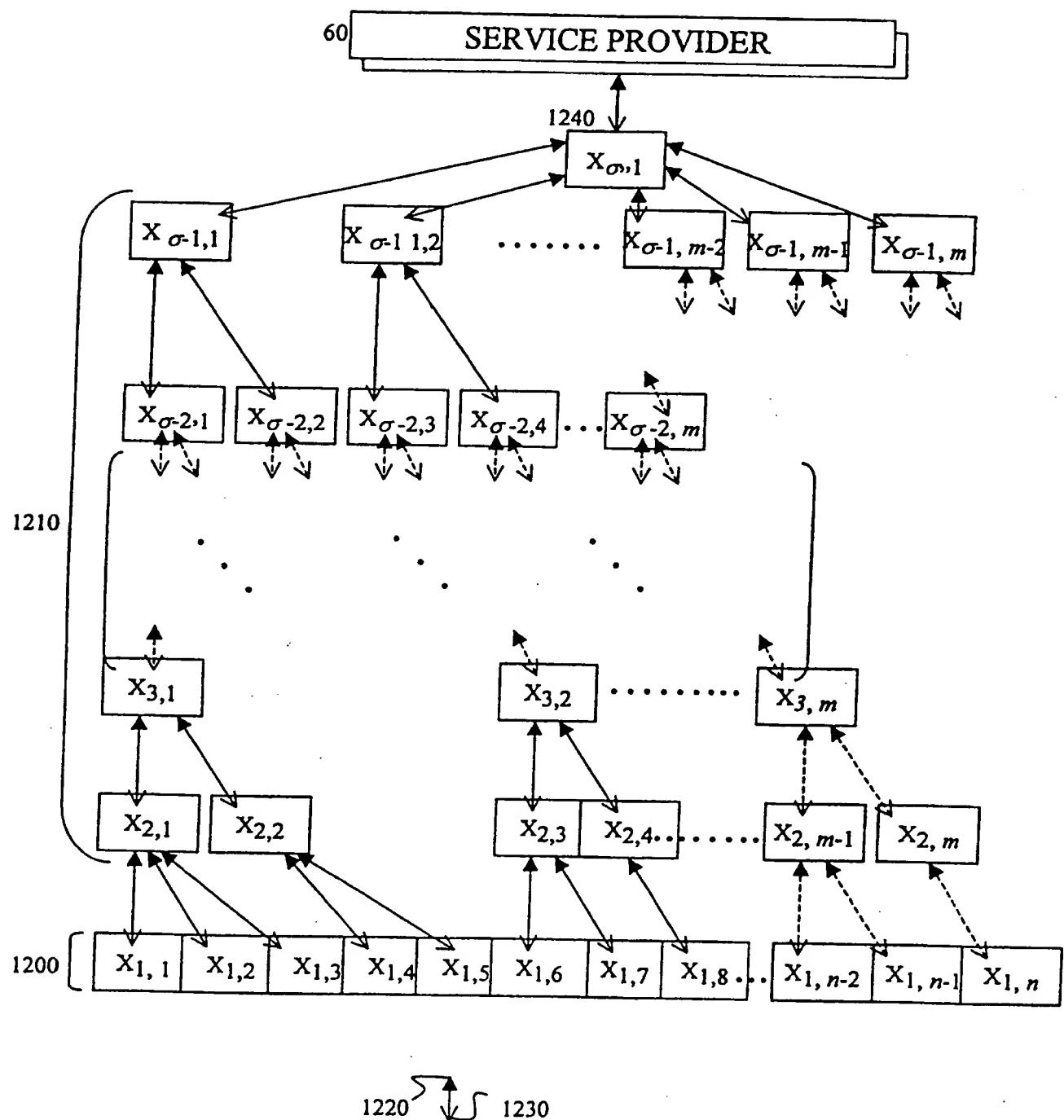
FIG. 12**SUBSTITUTE SHEET (RULE 26)**

FIG. 13

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US99/09938

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) H 04 K 1/00; H 04 L 9/00

US CL 380/30, 49

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

US 380/30, 49

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,544,246 A (MANDELBAUM et al) 06 August 1996, Figures 2-7, col. 2, lines 9-33.	1-11
Y	SCHNEIER, BRUCE. Applied Cryptography second edition. 1996, pgs. 43, and 51-54.	12-41
Y, A	US 5,671,279 A (ELGAMAL) 23 September 1997, figures 1-4, col. 3, lines 38-42.	12-41

 Further documents are listed in the continuation of Box C. See patent family annex.

- Special categories of cited documents.	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
- document referring to an oral disclosure, use, exhibition or other means		
- document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search
30 JULY 1999Date of mailing of the international search report
09 SEP 1999Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231
Facsimile No. (703) 305-3230

Authorized officer

DOUGLAS MEISLAHN

Telephone No. (703) 305-1338

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